AN INTERACTIVE MATRIX INTERPRETIVE SYSTEM FOR THE IBM 360/67

Robert Douglas Little

United States
Naval Postgraduate School

THESIS

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Robert Douglas Little
Lieutenant, United States Navy
B.S., United States Naval Academy, 1963

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ABSTRACT

The Matrix Interpretive System devised by Wilson and modified by Cantin has been transformed into an interactive program operable under a time sharing system. Several new commands have been added to extend the usefulness of the code and give it the capability to offline read, write and punch data, to plot graphs and contour maps and to integrate simple polynomial expressions.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

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I. INTRODUCTION

A. GENERAL DESCRIPTION

Many engineering problems in such fields as steady-state temperature distribution [Ref. 1], stress in elastic structures [Ref. 2], and fluid flows [Ref. 3] can be formulated as problems of numerical linear algebra. Until the advent of modern digital computers, all but the simplest of these problems had to be reserved to specialists for solutions. Even problems of moderate size required a considerable computational effort. The computer changed all of this. All of the simple matrix operations like multiplication, transposition, solution of eigen systems can be coded to solve individual problems. The computer program described in this report integrates a number of standard subprograms of linear algebra [Refs. 4,5,6,7] into a problem oriented computer language. This program, heretofore called: Matrix Interpretive System was coded in FORTRAN IV. The resulting matrix operations sub-language has a syntax and rules of its own as well as a certain number of diagnostic messages that can be automatically returned to the user of the language. The basic specification for the design of the language structure was that it had to be simple enough to be used by persons unfamiliar with computer programming. As written, the language could be used to solve stacks of problems sequentially; if an error is found in one of the problems a message is printed and a solution for the next problem is attempted. To be effective in a conversational mode at a remote station, the program had to be heavily modified so as

to leave effective control of the flow of operations to the user. This version of the code is called: Interactive Matrix Interpretive System.

The Interactive Matrix Interpetive System is a general program written in FORTRAN IV [Ref. 8], it is a problem oriented sub-language. The entire program is coded in double precision arithmetic. The only subroutines which are used but are not contained in the program are a square root and a natural log subroutine. The program uses 160,000 bytes of core storage.

B. HISTORICAL BACKGROUND

The original program was developed by Professor E. L. Wilson of the University of California in April 1963 for an IBM 7094. It was later adapted by Professor G. Cantin of the Naval Postgraduate School for a CDC 1604 in February 1966 and for the IBM 360/67 in August 1968.

C. OBJECTIVES

The objectives of the author's work have been to:

1. transform the program into an interactive system operable under time sharing from a remote typewriter station;

2. add operations to extend the capabilities of the program;

3. create a "USER'S MANUAL" to facilitate the use of the program.

II. GENERAL PROGRAM OPERATION

The Interactive Matrix Interpretive System will be referred to as IMIS in this and following sections of this report. IMIS is written in FORTRAN IV language for the IBM 360/67 time sharing system available at the Naval Postgraduate School (CP/CMS). A different version called DSMIS is used for batch processing. All operations are performed in double precision arithmetic. Matrices are stored internally in a single dimensional array, A, that is 10,000 double words in size. Matrix names are stored in an array called NAME. Arrays, NROW and NCOL, are used to store the number of rows and columns of each matrix.

The following is a brief description of the function and operation of most of the subroutines of IMIS. Some of the subroutines are straightforward and will not be discussed. A flow diagram of the program is presented in Figure 1.

A. MAIN PROGRAM AND SERVICE SUBROUTINES

1. Main Program

The Main program is used only to initialize internal variables and to call the main service subroutine, SMIS1.

2. Main Working Subroutine (SMIS1)

SMIS1 is the general working subroutine. Some of the operations such as duplication of a matrix and envelope of a matrix are carried out in SMIS1. The other operations are carried out in subroutines which are called from SMIS1. Most of the error messages are called from SMIS1.

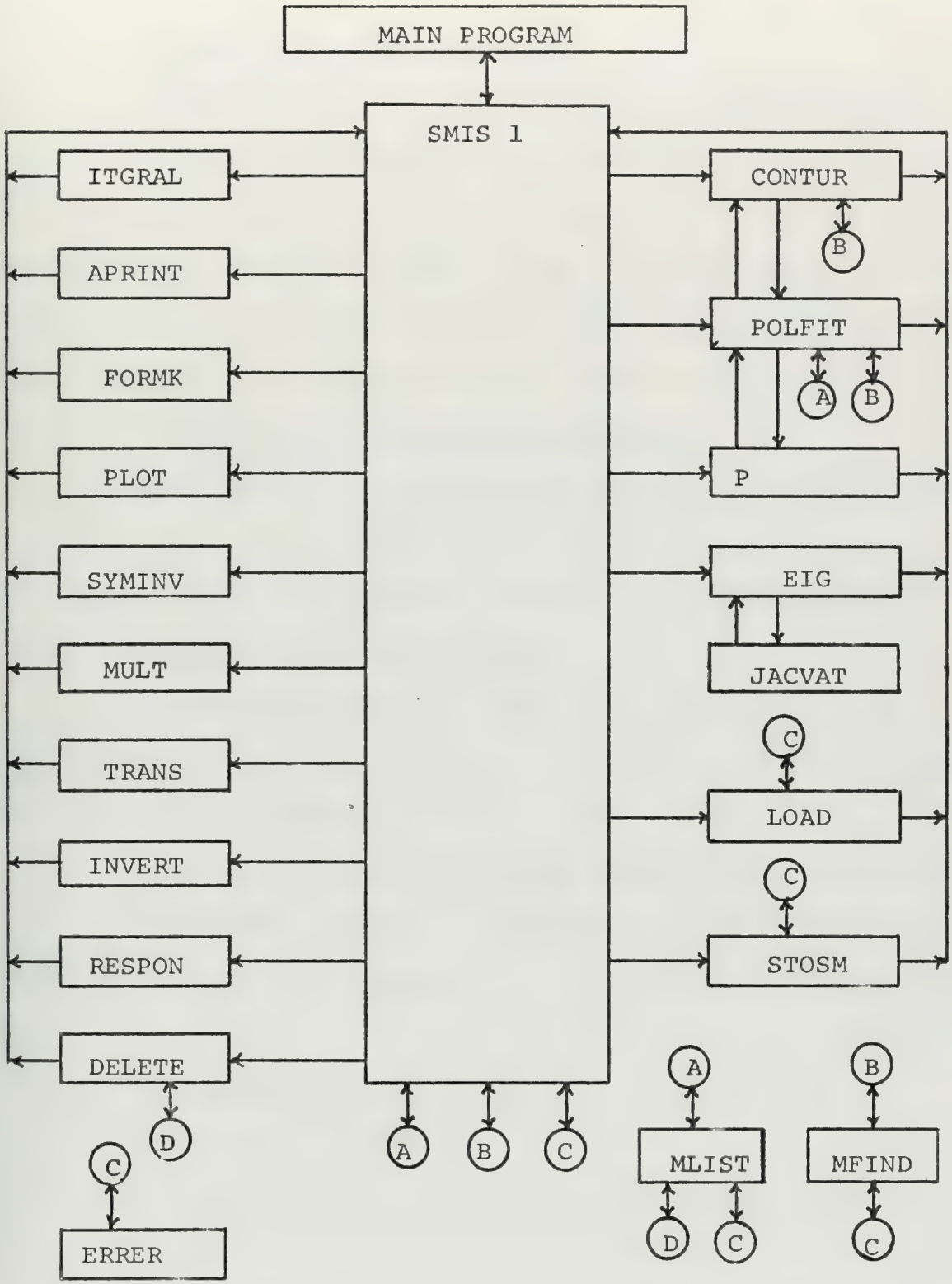

Figure 1. Functional Flow Diagram

3. Listing of a Matrix (MLIST)

MLIST stores each matrix by name, number of rows and columns and starting position in the array, A. It checks the name of a new matrix to be stored against the names of previously stored matrices to see if the name has been used before. If there is another matrix with the same name, the previously stored matrix will be deleted before the new matrix is stored.

4. Printing of Error Messages (ERRER)

When an error is made in an operational command, ERRER is called. It prints out an error message, deletes the current operational command and returns control to the typewriter.

5. Locating a Matrix (MFIND)

Locates the matrix or matrices to be used in an operation. It finds the number of rows and columns of a matrix and the starting position in the array A.

6. Calculating Eigenvalues and Eigenvectors (JACVAT)

Determines all of the eigenvalues and eigenvectors of a matrix. It uses the threshold cyclic Jacobi rotation method [Ref. 4].

7. Formation of Matrix N (P)

The bicubic polynomial,

$$P=C_1X^3Y^3+C_2X^3Y^2+C_3X^3Y+C_4X^3+C_5X^2Y^3+C_6X^2Y^2+C_7X^2Y+C_8X^2+$$

$$C_9XY^3+C_{10}XY^2+C_{11}XY+C_{12}X+C_{13}Y^3+C_{14}Y^2+C_{15}Y+C_{16}$$

is used in the polynomial fit operation. This polynomial can be written as

$$P = \langle F_i \rangle \{C_i\}_{i=1,2,\ldots,16}$$

where $\langle F_i \rangle = \langle X^3Y^3, X^3Y^2, X^3Y, X^3, X^2Y^3, X^2Y^2, X^2Y, X^2,$

$$XY^3, XY^2, XY, X, Y^3, Y^2, Y, 1 \rangle$$

and $\{C_i\} = \langle C_1, C_2, \ldots, C_{16} \rangle^T$. In the POLFIT operation, values of P at all of the sixteen nodal points of the grid shown in Figure 2 must be used to solve for all of the unknown coefficients of the polynomial using the following matrix equation:

$$\{P_i\} = [N] \{C_i\}_{i=1,2,\ldots,16}$$

where

$$[N] = \begin{bmatrix} \langle F_i^{(1)} \rangle \\ \langle F_i^{(2)} \rangle \\ \vdots \\ \langle F_i^{(16)} \rangle \end{bmatrix}$$

Subroutine P forms matrix N for use in the POLFIT operation. The bicubic polynomial, P, will be referred to as CUPOL in the following sections.

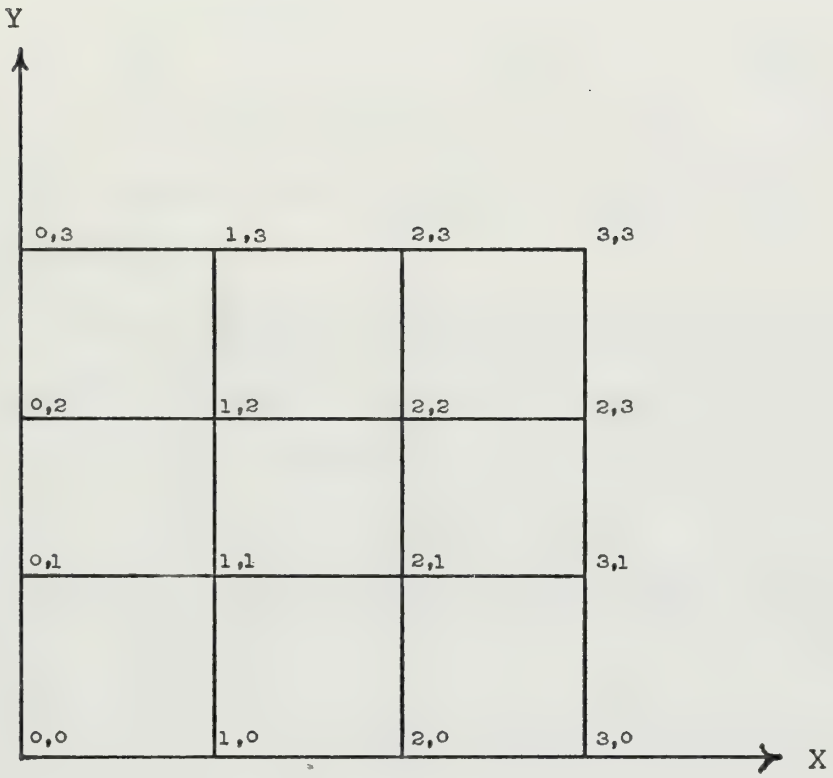

Figure 2. Grid For Subroutine P

B. OPERATION SUBROUTINES

1. Inverting a Symmetric Matrix (SYMINV)

SYMINV inverts a symmetric matrix, A, by Gauss elimination [Ref. 4]. If the matrix is not symmetric, it takes the average of the two numbers, A(i,j),A(j,i), and replaces both by the average value and prints a warning that the matrix was not symmetric.

2. Adding, Removing and Storing a Submatrix (STOSM)

STOSM is called to do three operations.

a) Store a submatrix at an indicated position in a matrix when called by the command, STOSM.

b) The command, RMVSM, calls STOSM to remove a submatrix from the original matrix.

c) ADDSM calls STOSM to add a submatrix to a matrix at an indicated position.

3. Function Generation (FUNGN)

This subroutine takes a function described by a set of points $(X_i,Y_i)_{i=1,2,\ldots,n}$, not necessarily equally spaced, and calculates, by straight line interpolation, ordinates at equally spaced values of X.

4. Printing of Graphs (PLOT)

PLOT prints a 10 inch by 10 inch graph of 1 to 4 curves. It automatically scales the graph to the maximum and minimum values of X and Y. The axes are plotted as

a) X------X

b) Y------Y

with the characters, X and Y, appearing at every inch on their respective axes. When all of the points are plotted on one side of either axis, an offset axis replaces the real axis and is indicated by

a) A------A offset X axis

b) B------B offset Y axis

The origin of the axes and the X and Y scale factors are calculated and printed below the graph.

5. Determining the Coefficients of a Bicubic Polynomial (POLFIT)

The 16 unknown coefficients of a bicubic polynomial surface can be determined in terms of 16 known values of the polynomial at 16 known values of the independent variables.

POLFIT solves the matrix equation,

$$[N]\ \{C\} = [P]$$

for the matrix of unknown coefficients, C, where matrix N is formed by the subroutine P. Matrix P is a matrix of the values of CUPOL at each nodal point and is the input to POLFIT.

6. Printing Contour Maps (CONTUR)

CONTUR prints a contour map of CUPOL. There are 21 possible contour lines which are represented by the alphabetic letters, A through J, O, Q through Z. The input is either the coefficients of CUPOL with the upper and lower limits of X and Y or the values of the function at the grid points used for POLFIT. In the latter case, POLFIT is called and the coefficients of CUPOL are calculated.

CUPOL is then scanned over the ranges of X and Y to determine the maximum and minimum Z ordinate. The range of Z is divided into 42 equal parts represented by alphabetic characters and blanks assigned to alternating contour values. CUPOL is then evaluated at each point on a line, the correct character inserted and the line printed.

7. Formation of a 2 by 2 Stiffness Matrix (FORMK)

FORMK forms the stiffness matrix [Ref. 9],

$$[K] = \begin{bmatrix} k_{11} & k_{12} \\ k_{21} & k_{22} \end{bmatrix}$$

for a simply supported beam having length, L, Young's Modulus, E, moment of inertia, I, shear modulus, G, and effective shear area, $\bar{A}$.

The stiffness coefficients are:

$$k_{11} = \frac{2EI}{L}\left(\frac{2+\beta}{1+2\beta}\right) = k_{22}$$

$$k_{12} = \frac{2EI}{L}\left(\frac{1-\beta}{1+\beta}\right) = k_{21}$$

where

$$\beta = \frac{6EI}{L^2\bar{A}G}$$

The matrix equation,

$$\begin{Bmatrix} M_1 \\ \\ M_2 \end{Bmatrix} = [K] \begin{Bmatrix} \theta_1 \\ \\ \theta_2 \end{Bmatrix}$$

relates end moments, M_1, M_2, to their corresponding rotations, θ_1, θ_2 as shown in Figure 3.

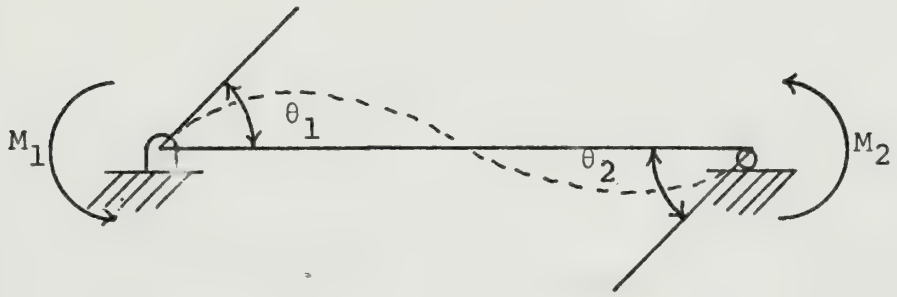

Figure 3. Simple Beam

8. Numerical Integration (ITGRAL)

The subroutine, ITGRAL, is capable of performing numerical integration of one and two dimensional functions described by discrete sets of points, either by Simpson's rule, or, if the function to be integrated is known, by Gaussian quadrature.

9. Numerical Integration of a Set of Differential Equations (RESPON)

In the study of vibrations of systems with many degrees of freedom, the following system of ordinary differential equations governs the problem:

$$[M]\{\ddot{X}\} + [C]\{\dot{X}\} + [K]\{X\} = \{P\} \qquad (1)$$

where

[M] is the mass matrix,

[C] is the damping matrix

and

[K] is the stiffness matrix.

In general, if

$$\{X\} = [V]\{x\} \qquad (2)$$

where matrix [V] is the matrix of undamped mode shapes and {x} is the vector of the time dependent amplitude function for each mode, we get after substitution of (2) into (1):

$$[M][V]\{\ddot{x}\} + [C][V]\{\dot{x}\} + [K][V]\{x\} = \{P\} \qquad (3)$$

After premultiplication by $[V]^T$ and the use of the orthogonality properties of normal modes:

$$[V]^T[M][V] = [\ulcorner m \lrcorner]$$

$$[V]^T[K][V] = [\ulcorner k \lrcorner] = [\ulcorner \omega^2 m \lrcorner]$$

$$[V]^T[C][V] = [\ulcorner c \lrcorner] = [\ulcorner 2\lambda\omega m \lrcorner] \text{ (a)}$$

(a) Such an orthogonality condition imposes some restrictions on the form of the damping matrix [C].

where

$$\lambda = \frac{c_i}{2m_i\omega_i}$$

and using the notation

$$[V]^T \{P\} = \{p\}$$

we get

$$[\sim m_\sim] \{\ddot{x}\} + [\sim 2\lambda\omega m_\sim] \{\dot{x}\} + [\sim \omega^2 m_\sim] \{x\} = \{p\} \qquad (4)$$

or

$$\{\ddot{x}\} + [\sim 2\lambda\omega_\sim] \{\dot{x}\} + [\sim \omega^2_\sim] \{x\} = \{p^*\} \qquad (5)$$

where $p_i^* = p_i/m_i$.

This last set of equations is completely decoupled and can easily be numerically integrated. The subroutine RESPON performs this task.

III. OPERATIONAL COMMANDS

The following is a list of the operations that IMIS contains. The operations must conform to the standard format shown in Figure 4. OPERATION stands for any of the symbolic command names mentioned below. A, B, C and D are matrices used as arguments of the operation. N1, N2, N3 and N4 are four integer arguments that must always be right justified. S1 and S2 are two floating point arguments. The arguments can be input or output values and are not all necessary for each command.

There are two versions of the matrix interpretive system in use at the Naval Postgraduate School. One is for time sharing and one for batch processing. The commands denoted by a "*" can only be used in conjunction with the time sharing option. The READ, WRITE and PUNCH commands make use of sequential input/output files which are available with the FORTRAN IV language [Ref. 8].(b)

The READ command uses the file FT04F001. This file is used to load matrices into IMIS from punched cards and is read into the computer prior to executing IMIS. Any data stored in the file is automatically erased when new data is read into the file.

File FT08F001 is used to store any output which the user wants to print offline. This file is not automatically erased

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(b) A certain knowledge of the CP/CMS time sharing system is needed when using a remote terminal of the computer. It is presumed that the reader is already familiar with this system [Ref. 10].

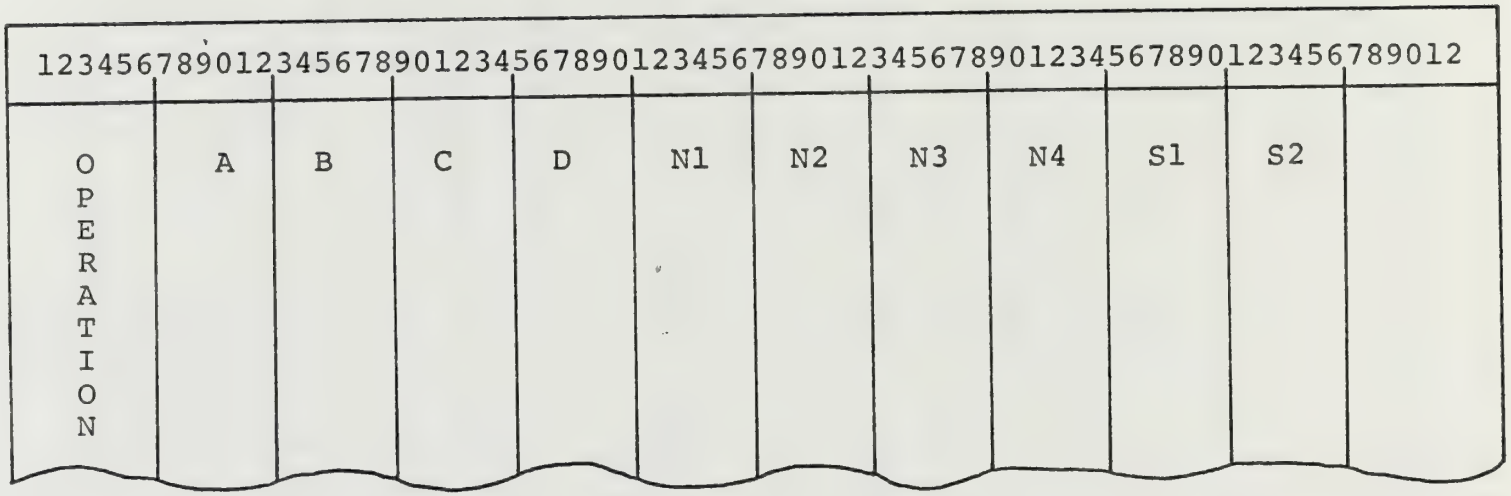


Figure 4. Standard Format

when new data is read into the file. New data is appended to the data that is already stored in the file. Therefore, the file must be erased before executing IMIS. To erase the file, the command,

ERASE$_b$FILE$_b$FT08F001

is used. After exiting from IMIS, the command,

OFFLINE$_b$PRINTCC$_b$FILE$_b$FT08F001

will cause the file to be printed on the offline printer.

The command, PUNCH, uses file FT07F001 to store data to be punched onto cards. This file appends new data at the end of old data so the file must be erased before using IMIS. The command,

ERASE$_b$FILE$_b$FT07F001

erases the file. To offline punch the data stored in the file, the command,

OFFLINE$_b$PUNCH$_b$FILE$_b$FT07F001

is issued after exiting from IMIS. Examples of the use of these files are given in the sample problems. The operational commands are:

START — This command causes the elimination of all matrices which are in core storage and must be the first command used in the solution of a problem. If an error is found during execution of a command, an error message is printed on the

typewriter, the current command eliminated and control returned to the typewriter. If an error is found during the execution of a problem with DSMIS, the current problem is automatically deleted and the remaining cards scanned until a new START or STOP command is found.

LOAD Matrix Load:

A = Name of matrix to be loaded.

N1 = Number of rows of matrix A.

N2 = Number of columns of matrix A.

N3 = Format control indicator for the data.

The elements of the matrix are typed or punched on cards row-wise after the LOAD command according to one of the options determined by the value of N3:

a. if N3= 1 or blank, the format is (12F6.0). A maximum of twelve numbers per line, using as many lines as required to write the entire matrix must be used. If the decimal point is omitted, it is assumed to be at the extreme right of the field.

b. if N3= 2, (6F12.0), 6 numbers per line in fields of 12 columns.

c. if N3= 3, (4F18.0), 4 numbers per line in fields of 24 columns.

d. if N3= 4, (3F24.0), 3 numbers per line in fields of 24 columns.

PRINT — Matrix Print:

A = Name of matrix to be printed.

N1= Number of lines, which follow the PRINT command, to be printed as a label for the matrix. Column 13 of the command card is used for carriage control in DSMIS only. A one in column 13 will cause the matrix to be printed on a separate output page.

REMARK — This operation causes the number of lines designated by N1, which follow the operation, to be printed as remarks.

STOP — This operation ends a run of problems and is the last command to be issued in a stack of problems. It can be used only once per run.

ZERO — Formation of a Null Matrix:

A = Name of null matrix.

N1= Number of rows of matrix A.

N2= Number of columns of matrix A.

ADD — Matrix Addition - [A] + [B] = [A]

Matrix A is replaced by the sum of matrices A and B.

SUB — Matrix Subtraction - [A] - [B] = [A]

Matrix A is replaced matrix A minus matrix B.

MULT — Matrix Multiplication - [A] • [B] = [C]

The product of matrix A times matrix B is generated and defined by matrix C.

TRANS — Matrix Transpose - $[B] = [A]^T$

The transpose of matrix A is generated and defined by matrix B.

INVERT — Matrix Inversion - $[A] = [A]^{-1}$

Matrix A is replaced by the inverse of itself.

SYMINV — Symmetric Matrix Inversion - $[A] = [A]^{-1}$

Symmetric matrix A is replaced by the inverse of itself.

STOSM — Store Submatrix in a Matrix:

A = Name of large matrix.

B = Name of submatrix to be stored.

N1= Row number in large matrix of first element of submatrix.

N2= Column number in large matrix of first element of submatrix.

Elements of A are replaced by elements of B in designated area.

STODG — Store Row Matrix on Diagonal of Matrix:

A = Name of square matrix.

B = Name of row matrix to be stored on diagonal of matrix A.

Diagonal elements of A are replaced by elements of B.

SCALE — Scalar Multiplication - [A] = S1·[A]

ADDSM — Add Submatrix to a Large Matrix:

A = Name of large matrix.

B = Name of submatrix to be added into large matrix.

N1= Row number in large matrix of first element of submatrix.

N2= Column number in large matrix of first element of submatrix.

RMVSM — Extracts Submatrix [B] from [A]:

A = Name of large matrix.

B = Name of submatrix defined as matrix.

N1= Row number in large matrix of first element of submatrix.

N2= Column number in large matrix of first element of submatrix.

N3= Number of rows in submatrix.

N4= Number of columns in submatrix.

Matrix A is not modified.

LOG — The Log of each Element

Each element in the matrix A is replaced by the natural log of the element.

MSCALE — Scalar Multiplication

Each element in the matrix A is replaced by B times the element where B has previously been defined as a 1 by 1 matrix.

RMVDG — Extracts Row Matrix B from Diagonal of Square matrix A.

A = Name of square matrix.

B = Name of row matrix composed of the diagonal elements of matrix A.

Matrix A is not modified.

EIGEN — Eigenvalues and Eigenvectors:

The eigenvalues and eigenvectors of the system, $[A][X]=\lambda[B][X]$, are determined where [A] is a symmetrical matrix and [B] is a diagonal matrix of positive elements stored as a row matrix.

A = Name of matrix A.

B = Name of matrix B.

C = Name of matrix of eigenvectors stored row-wise.

D = Name of row matrix of eigenvalues, λ.

N1= The number of eigenvectors to be calculated. The ordering of eigenvectors and eigenvalues is determined by the sign of N1 as follows:

a. If N1 is positive, eigenvalues are arranged in descending order.

b. If N1 is negative, eigenvalues are arranged in ascending order.

N2= Eigenvector normalizing.

a. If N2 is blank:

Eigenvectors are normalized so that $[C][B][C]^T = [I]$

b. If N2 is 1:

Eigenvalues are normalized so that $[A] = [C]^T [\lambda] [C]$

SQREL Square Root of Each Element

Each element in the matrix A is replaced by the square root of itself.

INVEL Inversion of Each Element

Each element in the matrix A is replaced by the reciprocal of itself.

DELETE Matrix Deletion

The matrix A is eliminated from core storage.

DUPL — Matrix Duplication:

A = Name of matrix to be duplicated.

B = Name of matrix defined to be identical with matrix A.

ENVEL — Envelope Value of Matrix

The maximum absolute value in each row of matrix A is printed along with its column number times an interval.

A = Name of matrix A.

Sl= Interval between columns.

RESPON — Numerical Integration of a Set of Differential Equations:

$$\{\ddot{x}\}+2\lambda[\omega]\{\dot{x}\}+[\omega^2]\{x\}=\{S\}P(t)$$

with initial conditions, $x(0)=\dot{x}(0)=0$.

A = Name of a row matrix containing the diagonal elements of matrix $[\omega]$. The dimension of A must be (1xn) where n is the number of equations in the set.

B = Name of a column matrix containing the elements of {S}. The dimension of B must be (nx1).

C = Name of a row matrix containing the values of the function P(t) evaluated at equal intervals, Δt:

$$P(0), P(\Delta t), P(2\Delta t), \ldots, P(m\Delta t)$$

The dimension of C depends on the choice of Δt which must be small for accurate results. The size of Δt should be determined by actual numerical experimentation with the command.

D = Name of the output matrix containing the calculated values of the variables as shown in Figure 5.

N1= Output interval i. The values of the n unknowns, {x}, are printed at $i\Delta t, 2i\Delta t, 3i\Delta t, \ldots$; if i=1, all of the values are printed.

S1= Value of the damping ratio, λ.

S2= Time increment, Δt, used in the numerical integration.

$$\begin{bmatrix} x_1(i\Delta t), x_1(2i\Delta t), x_1(3i\Delta t), \ldots \\ x_2(i\Delta t), x_2(2i\Delta t), x_2(3i\Delta t), \ldots \\ \vdots \\ x_n(i\Delta t), x_n(2i\Delta t), x_n(3i\Delta t), \ldots \end{bmatrix}$$

Fig. 5. OUTPUT MATRIX, D, FOR RESPON

FUNGN Function Generation:

A = Name of matrix which defines a function in terms of line segments $X_1,Y_1;X_2,Y_2;\cdots;X_n,Y_n$.(Nx2)

B = Name of matrix to be formed which is composed of the y ordinates at equal x ordinate intervals of the function defined by matrix A.

Nl= Number of y ordinates to be generated. The first ordinate will be equal to Y_1.

Sl= X ordinate interval.

FORMK Forms a 2x2 Element Stiffness Matrix:

A = Name of matrix to be formed.

The line following the command is as follows:

a. Columns 1-12 Moment of inertia of member, I.

b. Columns 13-24 Effective shear area of member, $\bar{A}$.

c. Columns 25-36 Length of member, L.

d. Columns 37-48 Modulus of elasticity of member, E.

The shear modulus, G, is assumed to be equal to E/2.4.

PUNCH — Punches Matrix onto Cards:

A = Name of matrix to be punched.

N1= Number of comment cards to be punched as a heading for matrix A.

After the PUNCH command is issued, the next line contains the format elected by the user as follows:

(NNTRR.SS)

where

NN= Number of elements per card.

RR= Field width per element.

SS= Number of significant digits.

T = Type of data field. T must be a standard F or D Fortran format.

* READ — Loads Matrices from file FT04F001

The load operation card must have a 1. in S1. The last card must be a Continue Operation card.

* CONT — Continue Operation

S1= 1.

Indicates that all matrices in file FT04F001 have been loaded into IMIS.

* WRITE — Writes Matrix into File FT08F001:

A = Name of matrix to be written.

N1= Number of lines of remarks to be

written as a label for the matrix A.

N2 must be equal to 1.

PLOT Plots One to Four Curves Described by Sets of Points Contained in Matrices A, B, C, D:

A = First matrix to be plotted on one graph. Plotted as a "+".

B = Second matrix to be plotted on one graph. Plotted as a "*".

C = Third matrix to be plotted on one graph. Plotted as a "O".

D = Fourth matrix to be plotted on one graph. Plotted as a ".".

* N3= 1. Offline print indicator. Graph will be stored in file FT08F001

N4= Number of lines of remarks to be printed at bottom of graph.

Matrices to be plotted do not have to have the same number of points. They have to be entered as N by 2 matrices with the first column the X co-ordinates and the second column the Y co-ordinates. When plotting more than one curve on the same graph, a conflict may arise if more than one curve passes

through the same point. The symbol printed at that point is determined by the following order: D, C, B and A.

POLFIT Determines the Coefficients of CUPOL:

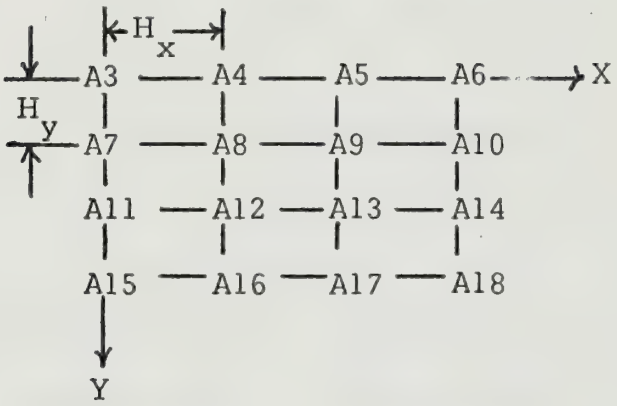
A = Input matrix. (18x1)

B = Output matrix of coefficients of CUPOL, $(C_1, C_2, \ldots, C_{16})$

where

A(1) = H_x

A(2) = H_y



and

$$CUPOL=C_1X^3Y^3+C_2X^3Y^2+C_3X^3Y+C_4X^3+$$

$$C_5X^2Y^3+C_6X^2Y^2+C_7X^2Y+C_8X^2+$$

$$C_9XY^3+C_{10}XY^2+C_{11}XY+C_{12}X+$$

$$C_{13}Y^3+C_{14}Y^2+C_{15}Y+C_{16}$$

CONTUR Contour Maps CUPOL:

N2= Number of lines of comments.

N3= Input type indicator.

a. N3= Blank or 1.

A = Input matrix. Same as for POLFIT command. (18x1)

B = Output matrix of coefficients of CUPOL. (16x1)

b. N3= 2

A = Input matrix. (20x1)

A(1) = Lower bound of X.

A(2) = Upper bound of X.

A(3) = Lower bound of Y.

A(4) = Upper bound of Y.

A(5) through A(20) are the coefficients of CUPOL.

* N4= Offline print indicator. Stores contour map in file FT09F001.

ITGRAL Integration of Functions Represented by Discrete Values or Polynomials:

A = Input matrix. (Rx1)

N3= Integration type indicator:

a. If N3= 1, Simpson's Rule for one dimension. R must be even.

A(1) = H_X

A(2) through A(R) are evenly spaced values of function.

b. If N3 = 2, Simpson's Rule for two dimensions.

A(1) = H_x

A(2) = H_y

A(3) through A(R) are values of function entered row-wise as for POLFIT.

R = N^2+2, N must be odd.

There must be the same number of values in both directions. H_x and H_y can be unequal.

c. If N3= 3, Gauss Quadrature for one dimension.

A(1) = Lower bound of X.

A(2) = Upper bound of X.

A(3) through A(14) are the coefficients of an 11th degree polynomial:

$$A_3X^{11}+A_4X^{10}+A_5X^9+A_6X^8+A_7X^7+A_8X^6+$$

$$A_9X^5+A_{10}X^4+A_{11}X^3+A_{12}X^2+A_{13}X+A_{14}$$

d. If N3 = 4, Gauss Quadrature for two dimensions.

A(1) = Lower bound of X.

A(2) = Upper bound of X.

A(3) = Lower bound of Y.

A(4) = Upper bound of Y.

A(5) through A(20) are coefficients of CUPOL.

IV. LIMITATIONS

A. SIZE AND NUMBER OF MATRICES

The storage available for all of the matrices in any problem is 80,000 bytes or 10,000 double words. This limit is arbitrary and controlled only by the total core storage available at any installation. For the naval Postgraduate School installation, 10,000 double words was selected in order to reduce turn around time in batch processing and reduce the size of the data set required for time sharing. The total number of matrices which can be stored is 100.

B. MATRIX NAMES

Each matrix is referred to by its name composed of one to six alphameric characters including blanks. The name is selected by the user when the matrix is first loaded or generated by an operation. If the name for a previously defined matrix is used later as a name of a new matrix, the former matrix is deleted before the operation is executed and is replaced by the new matrix. This is done so that there is only one matrix with a certain name at any one time.

C. PLOT

There are 200 points in the Y direction on the graph. The X direction has 130 points for the remote terminal printing and 160 points for the offline printer. The difference is due to the different number of lines per inch. The accuracy of the position of a point depends on the range in both the X and Y direction. The maximum error in the Y direction is the range of Y divided by 200. The maximum error in the X direction is

the range of X divided by either 130 for the remote terminal or 160 for the offline printer. If the X and Y ordinates of two or more points fall on the same nodal point on the graph, only one point will be plotted. If the points are from different matrices, the matrix hierarchy (see page 34) determines which will be plotted.

D. INTEGRATION

Integration by Simpson's Rule is restricted to equally spaced points in any one direction. The error is of the order of H_x^2 for integration in one dimension and of the order of H_x^2 times H_y^2 for two dimensions. H_x does not have to equal H_y but there has to be an odd number of points in any one direction. Integration by Gauss Quadrature for six Gauss ordinates is exact for all polynomials of degree eleven or less in one dimension and for CUPOL in two dimensions [Ref. 11]

E. POLFIT AND CONTUR

The polynomial, CUPOL, will pass through the values of the function at the nodal points of the grid but may not be a true representation in the space between nodal points. If the range of values of the function is less than 10^{-9}, a contour map will not be printed.

V. HOW TO CALL THE MATRIX INTERPRETIVE SYSTEM

A. TIME SHARING (IMIS VERSION)

At the Naval Postgraduate School, IMIS is stored in a library (AED) with the name, LIT, so that any number of users can use the system at any one time. In order to call LIT, it must be called as a subroutine. A Fortran program called IMIS has to be written as follows:

```
CALL LIT
STOP
END
```

There are two other libraries which must be loaded along with AED library in order to use LIT. This can be done with an executive program called SMIS as follows:

```
FORTRAN IMIS
GLOBAL LOADER TXTLIB AEDLIB SYSLIB
LOAD IMIS
START
```

SMIS is then executed with the command, $ SMIS. The computer will then type out the executive program with each command preceded by a time. Next it will type

```
EXECUTION BEGINS ...
```

At this time you are in IMIS and ready to begin the first problem. The first command will be START.

B. BATCH PROCESSING (DSMIS VERSION)

The first card must be a job card for the batch processing system as follows:

//aaaznnnn$_b$JOB(nnnn,ssssFP,TTTT), 'IDENTIFICATION'

where

aaa = The first three letters of the user's last name.

z = Job sequence number

nnnn= User's number.

ssss= Project number.

TTTT= Student section or faculty number.

The next six cards are control cards. Card five is used only when using the punch command. The cards are as follows stating in column one:

//JOBLIB$_b$DD$_b$DSNAME=DSMIS.F59CI,UNIT=2314,DISP=(OLD,KEEP),

//bbbbbbbbbbbbb^{V}OLUME=SER=MARY

//bb^{E}XEC$_b$PGM=DSMIS,REGION=160K

//FT06F001$_b$DD$_b$SYSOUT=A

//FT07F001$_b$DD$_b$SYSOUT=B

//FT05F001$_b$DD$_b$*

The "$_b$" is where blanks are left.

The problem deck follows with the first command a START command and the last a STOP command. The last card of the deck is a standard delimiter card:

/*

On the job request card, check the item marked DISK PACK under the SPECIAL INPUT heading and write in "MARY". If the punch command is being used, under the heading SPECIAL OUTPUT check the item marked PUNCHED CARDS.

VI. SAMPLE PROBLEMS

A. THE EIGEN SYSTEM

The matrix equation

$$[A]\ \{X\} = \lambda [B]\ \{X\}$$

where

$$[A] = \begin{bmatrix} 0.0 & -1.0 & 0.0 \\ -1.0 & 2.0 & -1.0 \\ 0.0 & -1.0 & 2.0 \end{bmatrix}$$

and

$$[B] = \begin{bmatrix} 1.5 & 0.0 & 0.0 \\ 0.0 & 2.0 & 0.0 \\ 0.0 & 0.0 & 2.5 \end{bmatrix}$$

is to be solved. The entire sequence of events is as shown below. Everything written in lower case was typed by the operator. The computer response is in upper case.

```
start

    START
load  a                                   3     3
    LOAD  A
    3 ROWS,     3 COLUMNS
0.0   -1.0   0.0  -1.0  2.0   -1.0  0.0   -1.0   2.0
load  b                                   1     3
    LOAD  B
    1 ROWS,     3 COLUMNS
1.5   2.0   2.5
eigen a     b     c     d               3     1
    EIGEN A     B     C     D
    3
print c
    PRINT C

                1             2             3
      1  -3.774271D-01 1.136139D 00-8.056459D-01
      2  -4.626117D-01 5.490667D-01 1.329088D 00
      3   1.069364D 00 6.385240D-01 2.906204D-01


print d
    PRINT D

                1             2             3
      1   1.505111D 00 5.934423D-01-2.985532D-01
```

```
trans c     ct
    TRANS C     CT
zero  x
    ZERO  X
    3 ROWS,     3 COLUMNS
stodg x     d
    STODG X     D
mult  ct    x     ctx
    MULT  CT    X     CTX
mult  ctx   c     a
    MULT  CTX   C     A
print a
    PRINT A
```

```
                1                2                3
      1  -1.471323D-13-1.000000D 00 1.902783D-13
      2  -1.000000D 00 2.000000D 00-1.000000D 00
      3   1.902228D-13-1.000000D 00 2.000000D 00
```

```
stop
    STOP
```

B. CONTOUR MAP

A contour map for a surface described by the ordinates at the sixteen nodal points of the grid shown on page 47 is desired.

$$[A] = \begin{bmatrix} 10.0 & 12.0 & 8.0 & 10.0 \\ 12.0 & 11.0 & 9.0 & 8.0 \\ 8.0 & 9.0 & 11.0 & 12.0 \\ 10.0 & 8.0 & 12.0 & 10.0 \end{bmatrix}$$

and

$H_x=H_y=1$

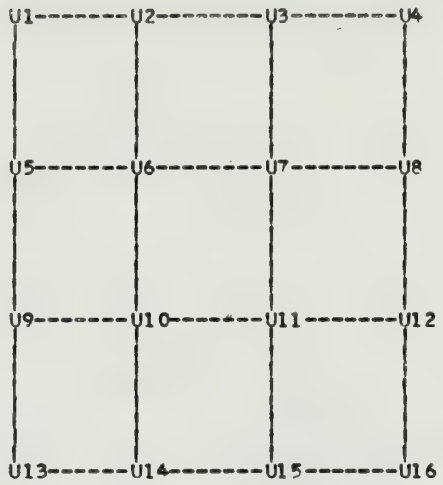
The results are as follows:

```
start

    START
load  a                                  18    1
    LOAD  A
   18 ROWS,      1 COLUMNS
1.     1.    10.    12.    8.     10.    12.     11.  9.      8.    8.      9.
11.    12.   10.    8.     12.    10.

contura      b
    CONTURA      B
```

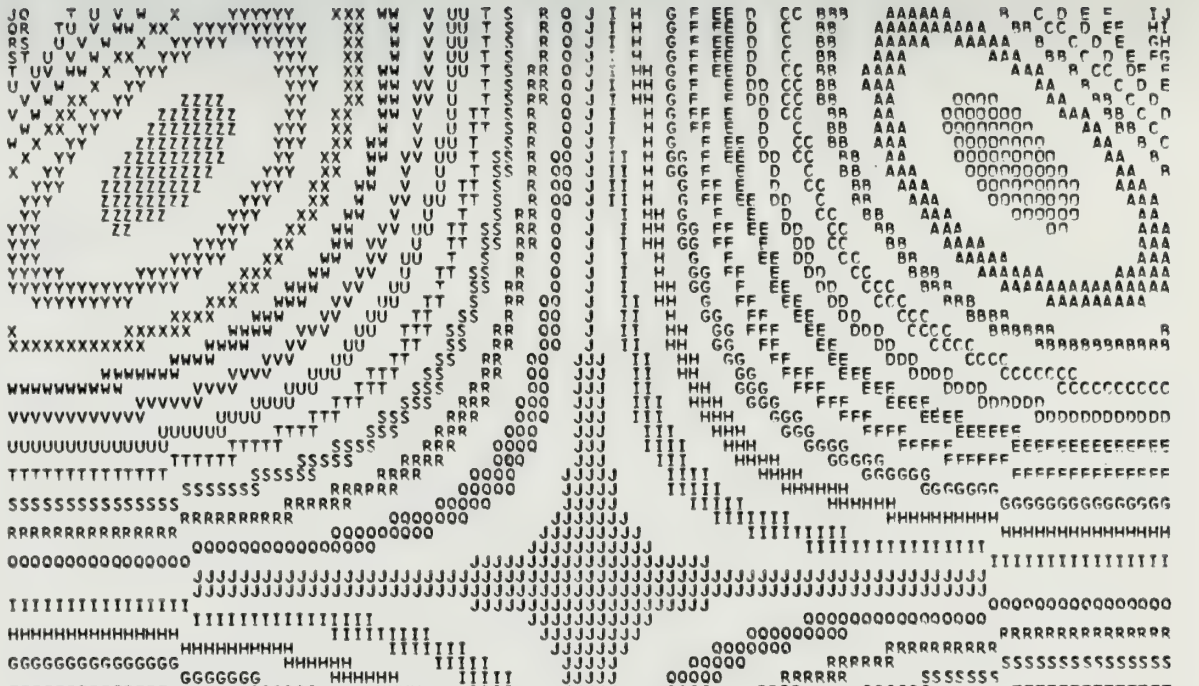
THIS IS THE FIRST PAGE OUTPUT USING GRID POINTS AS INPUT.



U1 =	10.000000	U2 =	12.000000	U3 =	8.000000	U4 =	10.000000
U5 =	12.000000	U6 =	11.000000	U7 =	9.000000	U8 =	8.000000
U9 =	8.000000	U10=	9.000000	U11=	11.000000	U12=	12.000000
U13=	10.000000	U14=	8.000000	U15=	12.000000	U16=	10.000000

O= 7.0814463545 RANGE(0.708145D 01 0.129186D 02)

A=	7.3733	B=	7.6652	C=	7.9570	D=	8.2489	E=	8.5407
F=	8.8326	G=	9.1244	H=	9.4163	I=	9.7081	J=	10.0000
Q=	10.2919	R=	10.5837	S=	10.8756	T=	11.1674	U=	11.4593
V=	11.7511	W=	12.0430	X=	12.3348	Y=	12.6267	Z=	12.9186



```
punch b
    PUNCH B
(4f15.8)


stop
    STOP
```

The command

offline punch file ft07f001

will cause the matrix B to be punched onto cards with the indicated format of four numbers per card with a field width of 15 and 8 significant figures.

If the input for the contour map had been the coefficients of CUPOL, the first page of output would have been as follows:

THIS IS THE FIRST PAGE OUTPUT COEFFICIENTS AS INPUT.

-0.333300 X3Y3	1.500000 X3Y2	-2.833000 X3Y	2.000000 X3
1.500000 X2Y3	-6.750000 X2Y2	12.750000 X2Y	-9.000000 X2
-2.833000 XY3	12.750000 XY2	-18.750000 XY	9.000000 X
2.000000 Y3	-9.000000 Y2	9.000000 Y	10.000000

O=	7.0837699378	RANGE(	0.708377D 01		0.129594D 02)		
A=	7.3776	B=	7.6713	C=	7.9651	D=	8.2589	E=	8.5527
F=	8.8465	G=	9.1402	H=	9.4340	I=	9.7278	J=	10.0216
Q=	10.3154	R=	10.6092	S=	10.9029	T=	11.1967	U=	11.4905
V=	11.7843	W=	12.0781	X=	12.3719	Y=	12.6656	Z=	12.9594

C. GRAPH

A plot of the function

$$x = e^{-15t} \sin(54.99t)$$

is desired from t = 0.0 to t = 0.3. The values were calculated in a separate program and the values of X were punched onto cards. They were prepared for offline reading into file FT04F001.

The first card is a standard CP67 offline read card as follows starting in column one.

CP67USERID$_{bb}$GUxxssss$_{bbbbbb}$TTTT

where

xx = Terminal number user will be using.

ssss= User's account number.

TTTT= User's name.

The second card is as follows:

OFFLINE$_b$READ$_b$FILE$_b$FT04F001

The next card is a LOAD command card with a 1. in S1.

```
LOAD A                  80   2                        1.
```

The matrix is punched onto cards row-wise with the same format as one of the options under IMIS and these cards follow the LOAD card. As many matrices as desired may be loaded in this manner. The last card is a continue card as follows:

```
CONT                                                 1.
```

This card indicates that all matrices have been read from file FT04F001. The deck is then loaded into the computer.

After logging onto the time sharing system, the command to read the file is as follows:

```
offline read *
   OFFLINE READ READ FILE FT04F001
```

IMIS is then executed and the sequence is as follows:

```
start

    START
read


    LOAD  A
   80 ROWS,      2 COLUMNS
write a                              1
    WRITE A
plot  a
    PLOT  A
```

Y= 0.96
X= 0.03
ORGIN: X= 0.0 Y= 0.0

```
stop
    STOP
```

The command

OFFLINE PRINTCC FILE FT08F001

will cause the matrix A to be printed on the offline printer.

VII. IMPROVEMENTS

This system is an open ended system, i.e., any matrix operation with fewer than four matrix arguments, four integer arguments and two scalar arguments can be coded as a new command and added to the system. As coded this program is sequential. Each command is executed once after it is read, no facilities for automatic repetitive execution of one or more commands is included. Such a feature would be very useful if it could be implemented without introducing extraneous complexities to the language.

```
C      MAIN PROGRAM                                                          LIT00010
       IMPLICIT REAL*8(A-H,O-Z)                                              LIT00020
       COMMON       XNAME(100),A(10000),W1(80),W2(80),W3(80),W4(80)          LIT00030
      1            ,NSIZE,NUM,NX,NR,NC,NNR,NNC,NDUM,NROW(100),NCOL(100)     LIT00040
      2,NN(100),NW1(80)                                                      LIT00050
C                                                                            LIT00060
CC     INITIALIZATION                                                        LIT00070
C                                                                            LIT00080
       NSIZE=4                                                               LIT00090
       WRITE (6,99)                                                          LIT00100
       NUM=0                                                                 LIT00110
       CALL SMIS1                                                            LIT00120
   99  FORMAT (1H1 )                                                         LIT00130
       STOP 1                                                                LIT00140
       END                                                                   LIT00150

       SUBROUTINE MLIST(MM,*)                                                LIT00160
       IMPLICIT REAL*8(A-H,O-Z)                                              LIT00170
C                                                                            LIT00180
CC     SUBROUTINE TO LIST MATRIX                                             LIT00190
C                                                                            LIT00200
       REAL*8 NAME,MM                                                        LIT00210
       COMMON       NAME(100),A(10000),W1(80),W2(80),W3(80),W4(80)          LIT00220
      1            ,NSIZE,NUM,NX,NR,NC,NNR,NNC,NDUM,NROW(100),NCOL(100)     LIT00230
      2,NN(100),NW1(80)                                                      LIT00240
       I=1                                                                   LIT00250
   15  IF (NUM-I) 30,10,10                                                   LIT00260
   10  IF (NAME(I)-MM) 20,25,20                                              LIT00270
   20  I=I+1                                                                 LIT00280
       GO TO 15                                                              LIT00290
   25  CALL DELETE(MM,&5)                                                    LIT00300
   30  NUM=NUM+1                                                             LIT00310
       NROW(NUM)=NR                                                          LIT00320
       NCOL(NUM)=NC                                                          LIT00330
       NAME(NUM)=MM                                                          LIT00340
       NN(NUM)=NSIZE                                                         LIT00350
       NX=NSIZE                                                              LIT00360
       NSIZE=NSIZE+NR*NC                                                     LIT00370
       IF (NUM-101) 45,40,45                                                 LIT00380
   40  CALL ERRER(6,&5)                                                      LIT00390
   45  IF(10001-NSIZE) 50,60,60                                              LIT00400
   50  CALL ERRER(5,&5)                                                      LIT00410
   60  RETURN                                                                LIT00420
    5  RETURN 1                                                              LIT00430
       END                                                                   LIT00440
```

```
      SUBROUTINE SMIS1                                                  LIT00450
      IMPLICIT REAL*8(A-H,O-Z)                                          LIT00460
      COMMON       XNAME(100),A(10000),W1(80),W2(80),W3(80),W4(80)      LIT00470
     1            ,NSIZE,NUM,NX,NR,NC,NNR,NNC,NDUM,NROW(100),NCOL(100) LIT00480
     2,NN(100),NW1(80)                                                  LIT00490
      REAL*8 NOPER,NSTART,LISTOP                                        LIT00500
      DIMENSION OPLIST(50),LISTOP(50),HED(10),FMT(10)                   LIT00510
      EQUIVALENCE (OPLIST(1),LISTOP(1)),(OPER,NOPER),(NSTART,START)     LIT00520
C                                                                       LIT00530
CC    LIST OF OPERATIONS                                                LIT00540
C                                                                       LIT00550
      DATA OPLIST/8HZZZZZZ   ,8HPRINT    ,8HZERO     ,8HDELETE   ,8HDUPL  LIT00560
     1,8HADD      ,8HSUB      ,8HSCALE    ,8HMULT     ,8HINVERT   ,8HTRANS LIT00570
     2,8HSTOSM    ,8HRMVSM    ,8HWRITE    ,8HREAD     ,8HSTART    ,8HREWIND LIT00580
     3,8HEIGEN    ,8HRESPON   ,8HFUNGN    ,8HSQREL    ,8HINVEL    ,8HSTOP  LIT00590
     4,8HENVEL    ,8HADDSM    ,8HREMARK   ,8HSYMINV   ,8HFORMK    ,8HLOG   LIT00600
     5,8HSTODG    ,8HRMVDG    ,8HMSCALE   ,8HLOAD     ,8HCONT     ,8HPLOT  LIT00610
     6,8HITGRAL   ,8HCONTUR   ,8HPOLFIT   ,8HPUNCH    /,START/8HSTART    /, LIT00620
     7XZR/8H         /                                                  LIT00630
   9  CONTINUE                                                          LIT00640
      OPER=XZR                                                          LIT00650
      XA=XZR                                                            LIT00660
      XB=XZR                                                            LIT00670
      XC=XZR                                                            LIT00680
      XD=XZR                                                            LIT00690
      DO 1 I=1,80                                                       LIT00700
      W1(I)=0.0D0                                                       LIT00710
      W2(I)=0.0D0                                                       LIT00720
      W3(I)=0.0D0                                                       LIT00730
      W4(I)=0.0D0                                                       LIT00740
   1  NW1(I)=0                                                          LIT00750
      DO 2 I=1,10000                                                    LIT00760
   2  A(I)=0.0D0                                                        LIT00770
      DO 3 I=1,100                                                      LIT00780
      NROW(I)=0                                                         LIT00790
      NCOL(I)=0                                                         LIT00800
      NN(I)=0                                                           LIT00810
C                                                                       LIT00820
CC    READ AND PRINT OF CONTROL INFORMATION                             LIT00830
C                                                                       LIT00840
   3  XNAME(I)=XZR                                                      LIT00850
      NUMOP=39                                                          LIT00860
   4  CONTINUE                                                          LIT00870
   5  READ(5,101)  OPER,XA,XB,XC,XD,NR,NC,NNR,NNC,SCAL1,SCAL2           LIT00880
      IF (NSTART-NOPER) 7,6,7                                           LIT00890
  27  READ(4,101) OPER,XA,XB,XC,XD,NR,NC,NNR,NNC,SCAL1,SCAL2            LIT00900
      IF(SCAL1-1.0) 28,6,28                                             LIT00910
  28  CALL ERRER(10,&5)                                                 LIT00920
```

```
    6 WRITE(6,99)                                                          LIT00930
    7 WRITE(6,100) OPER,XA,XB,XC,XD                                        LIT00940
C                                                                          LIT00950
CC     DETERMINATION OF OPERATION                                          LIT00960
C                                                                          LIT00970
      I=1                                                                  LIT00980
   10 IF(NUMOP-I) 20,30,30                                                 LIT00990
   20 CALL ERRER(3,&5)                                                     LIT01000
   30 IF (LISTOP(I)-NOPER) 40,50,40                                        LIT01010
   40 I=I+1                                                                LIT01020
      GO TO 10                                                             LIT01030
   50 GO TO ( 20,120,130,140,150,160,170,180,190,200,210,220,230,240,      LIT01040
     1  250,260,270,280,290,300,310,320,330,340,350,360,370,380,390,       LIT01050
     2  400,410,420,430,440,450,460,470,480,490),I                         LIT01060
C                                                                          LIT01070
CC     MATRIX LOAD                                                         LIT01080
C                                                                          LIT01090
  430 WRITE(6,102) NR,NC                                                   LIT01100
      CALL MLIST(XA,&5)                                                    LIT01110
      NA=NX                                                                LIT01120
      CALL LOAD(A(NA),NR,NC,NNR,SCAL1,&5)                                  LIT01130
      IF(SCAL1.EQ.1.0) GO TO 27                                            LIT01140
      GO TO 5                                                              LIT01150
C                                                                          LIT01160
CC      CONTINUE OPERATION                                                 LIT01170
C                                                                          LIT01180
  440 GO TO 5                                                              LIT01190
C                                                                          LIT01200
CC     MATRIX PRINT                                                        LIT01210
C                                                                          LIT01220
  120 IF(XB.EQ.1.0D0) WRITE(6,99)                                          LIT01230
  123 WRITE(6,109)                                                         LIT01240
      K=1                                                                  LIT01250
      GO TO 361                                                            LIT01260
  121 CALL MFIND(XA,&5)                                                    LIT01270
  126 NA=NX                                                                LIT01280
      CALL APRINT(A(NA),NR,NC,NNR)                                         LIT01290
      WRITE(6,109)                                                         LIT01300
      GO TO 5                                                              LIT01310
C                                                                          LIT01320
CC     MATRIX ZERO                                                         LIT01330
C                                                                          LIT01340
  130 WRITE(6,102) NR,NC                                                   LIT01350
      CALL MLIST(XA,&5)                                                    LIT01360
      DO 135 I=NX,NSIZE                                                    LIT01370
  135 A(I)=0.0D0                                                           LIT01380
      GO TO 5                                                              LIT01390
C                                                                          LIT01400
```

```
C      DELETE OPERATION                                                  LIT01410
C                                                                        LIT01420
  140 CALL DELETE(XA,&5)                                                 LIT01430
      GO TO 5                                                            LIT01440
C                                                                        LIT01450
C      DUPLICATION OF MATRIX                                             LIT01460
C                                                                        LIT01470
  150 CALL MFIND(XA,&5)                                                  LIT01480
      CALL MLIST(XB,&5)                                                  LIT01490
      NB=NX-1                                                            LIT01500
      CALL MFIND(XA,&5)                                                  LIT01510
      NA=NX-1                                                            LIT01520
      NS=NR*NC                                                           LIT01530
      DO 155 I=1,NS                                                      LIT01540
      J=I+NB                                                             LIT01550
      K=I+NA                                                             LIT01560
  155 A(J)=A(K)                                                          LIT01570
      GO TO 5                                                            LIT01580
C                                                                        LIT01590
C      ADDITION OR SUBTRACTION OF MATRICES                               LIT01600
C                                                                        LIT01610
  160 TAG=1.0                                                            LIT01620
      GO TO 171                                                          LIT01630
  170 TAG=-1.0                                                           LIT01640
  171 CALL MFIND(XA,&5)                                                  LIT01650
      NA=NX-1                                                            LIT01660
      NNR=NR                                                             LIT01670
      NNC=NC                                                             LIT01680
      CALL MFIND(XB,&5)                                                  LIT01690
      NB=NX-1                                                            LIT01700
      IF(NR-NNR) 173,172,173                                             LIT01710
  172 IF(NC-NNC) 173,174,173                                             LIT01720
  173 CALL ERRER(1,&5)                                                   LIT01730
  174 NS=NR*NC                                                           LIT01740
  175 DO 176 I=1,NS                                                      LIT01750
      J=I+NA                                                             LIT01760
      K=I+NB                                                             LIT01770
  176 A(J)=A(J)+TAG*A(K)                                                 LIT01780
      GO TO 5                                                            LIT01790
C                                                                        LIT01800
C      SCALAR MULTIPLICATION                                             LIT01810
C                                                                        LIT01820
  180 WRITE(6,103) SCAL1                                                 LIT01830
      CALL MFIND(XA,&5)                                                  LIT01840
      NA=NX                                                              LIT01850
      NB=NX-1+NR*NC                                                      LIT01860
      DO 185 I=NA,NB                                                     LIT01870
  185 A(I)=SCAL1*A(I)                                                    LIT01880
```

```
      GO TO 5                                                          LIT01890
C                                                                      LIT01900
CC    MATRIX MULTIPLICATION                                            LIT01910
C                                                                      LIT01920
  190 CALL MFIND(XA,&5)                                                LIT01930
      NRA=NR                                                           LIT01940
      NCA=NC                                                           LIT01950
      CALL MFIND(XB,&5)                                                LIT01960
      NRB=NR                                                           LIT01970
      NCB=NC                                                           LIT01980
      IF(NCA-NRB) 191,192,191                                          LIT01990
  191 CALL ERRER(1,&5)                                                 LIT02000
  192 NR=NRA                                                           LIT02010
      CALL MLIST(XC,&5)                                                LIT02020
      ND=NX                                                            LIT02030
      CALL MFIND(XA,&5)                                                LIT02040
      NA=NX                                                            LIT02050
      CALL MFIND(XB,&5)                                                LIT02060
      NB=NX                                                            LIT02070
      CALL MULT(NRA,A(NA),NCA,A(NB),NCB,A(ND))                         LIT02080
      GO TO 5                                                          LIT02090
C                                                                      LIT02100
CC    MATRIX INVERSION                                                 LIT02110
C                                                                      LIT02120
  200 CALL MFIND(XA,&5)                                                LIT02130
      NA=NX                                                            LIT02140
      IF(NR-NC) 201,202,201                                            LIT02150
  201 CALL ERRER(1,&5)                                                 LIT02160
  202 CALL INVERT(A(NA),W3(1),NW1(1),NR)                               LIT02170
      GO TO 5                                                          LIT02180
C                                                                      LIT02190
CC    MATRIX TRANSPOSE                                                 LIT02200
C                                                                      LIT02210
  210 CALL MFIND(XA,&5)                                                LIT02220
      NRA=NR                                                           LIT02230
      NR=NC                                                            LIT02240
      NC=NRA                                                           LIT02250
      CALL MLIST(XB,&5)                                                LIT02260
      NB=NX                                                            LIT02270
      CALL MFIND(XA,&5)                                                LIT02280
      NA=NX                                                            LIT02290
      CALL TRANS(A(NA),A(NB),NRA,NC)                                   LIT02300
      GO TO 5                                                          LIT02310
C                                                                      LIT02320
CC    STORE SUBMATRIX                                                  LIT02330
C                                                                      LIT02340
  220 NTAG=1                                                           LIT02350
  221 J=NR                                                             LIT02360
```

```
      K=NC                                                              LIT02370
      CALL MFIND(XB,&5)                                                 LIT02380
      GO TO 235                                                         LIT02390
C                                                                       LIT02400
CC    REMOVE SUBMATRIX                                                  LIT02410
C                                                                       LIT02420
  230 J=NR                                                              LIT02430
      K=NC                                                              LIT02440
      NR=NNR                                                            LIT02450
      NC=NNC                                                            LIT02460
      WRITE(6,102) NR,NC                                                LIT02470
      NTAG=0                                                            LIT02480
      CALL MLIST(XB,&5)                                                 LIT02490
  235 WRITE(6,104) J,K                                                  LIT02500
      NB=NX                                                             LIT02510
      NRB=NR                                                            LIT02520
      NCB=NC                                                            LIT02530
      CALL MFIND(XA,&5)                                                 LIT02540
      NA=NX                                                             LIT02550
      NRA=NR                                                            LIT02560
      NCA=NC                                                            LIT02570
      CALL STOSM(A(NA),A(NB),NRA,NCA,NRB,NCB,J,K,NTAG)                  LIT02580
      GO TO 5                                                           LIT02590
C                                                                       LIT02600
CC    WRITE MATRIX IN FILE FT08F001                                     LIT02610
C                                                                       LIT02620
  240 IF(NNR-1) 122,124,122                                             LIT02630
  122 CALL ERRER(11,&5)                                                 LIT02640
  124 WRITE(8,111) XA                                                   LIT02650
      GO TO 123                                                         LIT02660
C                                                                       LIT02670
CC    READ MATRIX FROM FILE FT04F001                                    LIT02680
C                                                                       LIT02690
  250 GO TO 27                                                          LIT02700
C                                                                       LIT02710
CC    START                                                             LIT02720
C                                                                       LIT02730
  260 NSIZE=4                                                           LIT02740
      NUM=0                                                             LIT02750
      GO TO 9                                                           LIT02760
C                                                                       LIT02770
CC    REWIND TAPE NR                                                    LIT02780
C                                                                       LIT02790
  270 CALL ERRER(9,&5)                                                  LIT02800
C                                                                       LIT02810
CC    EIGENVALUES AND EIGENVECTORS                                      LIT02820
C                                                                       LIT02830
  280 M=NR                                                              LIT02840
```

```
      N2=NC                                                                  LIT02850
      CALL MFIND(XA,&5)                                                      LIT02860
      IF (NR-NC) 281,282,281                                                 LIT02870
  281 CALL ERRER(1,&5)                                                       LIT02880
  282 N=NR                                                                   LIT02890
      NEV=N                                                                  LIT02900
      NR=1                                                                   LIT02910
      CALL MLIST(XD,&5)                                                      LIT02920
      NR=IABS (M)                                                            LIT02930
      CALL MLIST(XC,&5)                                                      LIT02940
      NE=NX                                                                  LIT02950
      CALL MFIND(XA,&5)                                                      LIT02960
      NA=NX                                                                  LIT02970
      CALL MFIND(XB,&5)                                                      LIT02980
      NB=NX                                                                  LIT02990
      CALL MFIND(XD,&5)                                                      LIT03000
      ND=NX                                                                  LIT03010
      WRITE(6,107) M                                                         LIT03020
      CALL EIG(A(NA),A(NB),A(NE),A(ND),NEV,M,N2,N)                           LIT03030
      GO TO 5                                                                LIT03040
C                                                                            LIT03050
CC    RESPONSE CALCULATION                                                   LIT03060
C                                                                            LIT03070
  290 N=NR                                                                   LIT03080
      WRITE(6,107) N,SCAL1,SCAL2                                             LIT03090
      CALL MFIND(XA,&5)                                                      LIT03100
      M=NC                                                                   LIT03110
      CALL MFIND(XC,&5)                                                      LIT03120
      NC=NC/N                                                                LIT03130
      NR=M                                                                   LIT03140
      CALL MLIST(XD,&5)                                                      LIT03150
      ND=NX                                                                  LIT03160
      CALL MFIND(XA,&5)                                                      LIT03170
      NA=NX                                                                  LIT03180
      CALL MFIND(XB,&5)                                                      LIT03190
      NB=NX                                                                  LIT03200
      CALL MFIND(XC,&5)                                                      LIT03210
      NNC=NX                                                                 LIT03220
      NTAG=1                                                                 LIT03230
      IF(NR-1) 396,394,396                                                   LIT03240
  394 NTAG=0                                                                 LIT03250
  396 L=NC                                                                   LIT03260
      CALL RESPON(A(NA),A(NB),A(NNC),A(ND),M,N,L,SCAL1,SCAL2,NTAG)           LIT03270
      GO TO 5                                                                LIT03280
C                                                                            LIT03290
CC    FUNCTION GENERATION                                                    LIT03300
C                                                                            LIT03310
  300 N=NR                                                                   LIT03320
```

```
      WRITE(6,107) N,SCAL1                                              LIT03330
      NR=1                                                              LIT03340
      NC=N                                                              LIT03350
      CALL MLIST(XB,&5)                                                 LIT03360
      K=NX                                                              LIT03370
      NH=NX+N-1                                                         LIT03380
      CALL MFIND(XA,&5)                                                 LIT03390
      L=NX                                                              LIT03400
      TIM =A(L)                                                         LIT03410
      GO TO 302                                                         LIT03420
  301 IF (A(L)-TIM) 302,302,306                                         LIT03430
  302 DT=A(L+2)-A(L)                                                    LIT03440
      DP=A(L+3)-A(L+1)                                                  LIT03450
      L=L+2                                                             LIT03460
      IF (DT) 304,302,305                                               LIT03470
  304 CALL ERRER(1,&5)                                                  LIT03480
  305 SLOPE=DP/DT                                                       LIT03490
  306 A(K)=A(L-1)+(TIM -A(L-2))*SLOPE                                   LIT03500
  308 TIM =TIM +SCAL1                                                   LIT03510
      K=K+1                                                             LIT03520
        IF (NH-K) 5,301,301                                             LIT03530
C                                                                       LIT03540
CC    SQUARE ROOT OF EACH ELEMENT                                       LIT03550
C                                                                       LIT03560
  310 CALL MFIND(XA,&5)                                                 LIT03570
      NA=NX                                                             LIT03580
      NB=NA+NR*NC-1                                                     LIT03590
      DO 315 K=NA,NB                                                    LIT03600
  315 A(K)=DSQRT(A(K))                                                  LIT03610
      GO TO 5                                                           LIT03620
C                                                                       LIT03630
CC    INVERSION OF EACH ELEMENT                                         LIT03640
C                                                                       LIT03650
  320 CALL MFIND(XA,&5)                                                 LIT03660
      NA=NX                                                             LIT03670
      NB=NA+NR*NC-1                                                     LIT03680
      DO 325 K=NA,NB                                                    LIT03690
  325 A(K)=1./A(K)                                                      LIT03700
      GO TO 5                                                           LIT03710
  330 RETURN                                                            LIT03720
C                                                                       LIT03730
CC    ENVELOPE VALUES OF MATRIX                                         LIT03740
C                                                                       LIT03750
  340 WRITE(6,101) XB                                                   LIT03760
      K=2                                                               LIT03770
      GO TO 361                                                         LIT03780
  341 CALL MFIND(XA,&5)                                                 LIT03790
      NA=NX                                                             LIT03800
```

```
      NR=NR                                                          LIT03810
      NC=NC                                                          LIT03820
      K=NA                                                           LIT03830
      DO 347 I=1,NR                                                  LIT03840
      AMAX=0.0                                                       LIT03850
      TIM =SCAL1                                                     LIT03860
      DO 346 J=1,NC                                                  LIT03870
      XA=DABS(A(K))                                                  LIT03880
      IF(AMAX-XA) 344,345,345                                        LIT03890
  344 AMAX=XA                                                        LIT03900
      TMAX=TIM                                                       LIT03910
  345 K=K+1                                                          LIT03920
  346 TIM =TIM +SCAL1                                                LIT03930
  347 WRITE(6,108) I,TMAX,AMAX                                       LIT03940
       WRITE(6,101) XB                                               LIT03950
      GO TO 5                                                        LIT03960
C                                                                    LIT03970
CC    ADD SUBMATRIX                                                  LIT03980
C                                                                    LIT03990
  350 NTAG=-1                                                        LIT04000
      GO TO 221                                                      LIT04010
C                                                                    LIT04020
CC    READ AND PRINT OF REMARK CARDS                                 LIT04030
C                                                                    LIT04040
  360 K=3                                                            LIT04050
  361 IF(NR) 366,366,364                                             LIT04060
  364 IF(NNR.EQ.1) GO TO 367                                         LIT04070
      DO 365 I=1,NR                                                  LIT04080
      READ(5,105) HED                                                LIT04090
  365 WRITE(6,110) HED                                               LIT04100
  366 GO TO (121,341,5),K                                            LIT04110
  367 DO 368 I=1,NR                                                  LIT04120
      READ(5,105) HED                                                LIT04130
  368 WRITE(8,110) HED                                               LIT04140
      GO TO 366                                                      LIT04150
C                                                                    LIT04160
CC    INVERSION OF SYMMETRICAL MATRIX                                LIT04170
C                                                                    LIT04180
  370 CALL MFIND(XA,&5)                                              LIT04190
      NA=NX                                                          LIT04200
      IF (NR-NC) 372,375,372                                         LIT04210
  372 CALL ERRER(1,&5)                                               LIT04220
  375 CALL SYMINV(A(NA),NR,W1(1),W3(1))                              LIT04230
      GO TO 5                                                        LIT04240
C                                                                    LIT04250
CC    FORM 2X2 MATRIX                                                LIT04260
C                                                                    LIT04270
  380 NR=2                                                           LIT04280
```

```
      NC=2                                                          LIT04290
      CALL MLIST(XA,&5)                                             LIT04300
      NA=NX                                                         LIT04310
      CALL FORMK(A(NA))                                             LIT04320
      GO TO 5                                                       LIT04330
C                                                                   LIT04340
CC    TAKES A LOG OF A MATRIX                                       LIT04350
C                                                                   LIT04360
  390 CALL MFIND(XA,&5)                                             LIT04370
      IH=NX-1+NR*NC                                                 LIT04380
      IL=NX                                                         LIT04390
      DO 395 I=IL,IH                                                LIT04400
  395 A(I)= DLOG(A(I))                                              LIT04410
      GO TO 5                                                       LIT04420
C                                                                   LIT04430
CC    STORES ROW (B) ON DIAGONAL OF (A)                             LIT04440
C                                                                   LIT04450
  400 CALL MFIND(XA,&5)                                             LIT04460
      K=NX                                                          LIT04470
      CALL MFIND(XB,&5)                                             LIT04480
      IL=NX                                                         LIT04490
      IH=NX-1+NC                                                    LIT04500
      DO 405 I=IL,IH                                                LIT04510
      A(K)=A(I)                                                     LIT04520
  405 K=K+NC+1                                                      LIT04530
      GO TO 5                                                       LIT04540
C                                                                   LIT04550
CC    REMOVES ROW (B) FROM DIAGONAL OF (A)                          LIT04560
C                                                                   LIT04570
  410 CALL MFIND(XA,&5)                                             LIT04580
      NR=1                                                          LIT04590
      CALL MLIST(XB,&5)                                             LIT04600
      IL=NX                                                         LIT04610
      IH=NX-1+NC                                                    LIT04620
      CALL MFIND(XA,&5)                                             LIT04630
      K=NX                                                          LIT04640
      DO 415 I=IL,IH                                                LIT04650
      A(I)=A(K)                                                     LIT04660
  415 K=K+NC+1                                                      LIT04670
      GO TO 5                                                       LIT04680
C                                                                   LIT04690
CC    MULTIPLIES A BY B(1,1)                                        LIT04700
C                                                                   LIT04710
  420 CALL MFIND(XB,&5)                                             LIT04720
      I=NX                                                          LIT04730
      SCAL1=A(I)                                                    LIT04740
      GO TO 180                                                     LIT04750
C                                                                   LIT04760
```

```
C      PLOT OPERATION                                                    LIT04770
C                                                                        LIT04780
  450 INR=NNR                                                            LIT04790
      NAA=0.0                                                            LIT04800
      NAB=0.0                                                            LIT04810
      NAC=0.0                                                            LIT04820
      NBA=0.0                                                            LIT04830
      NBB=0.0                                                            LIT04840
      NBC=0.0                                                            LIT04850
      CALL MFIND(XA,&5)                                                  LIT04860
      NA=NX                                                              LIT04870
      NB=NA+NC*NR-1                                                      LIT04880
      IF(XB.EQ.XZR) GO TO 451                                            LIT04890
      CALL MFIND(XB,&5)                                                  LIT04900
      NAA=NX                                                             LIT04910
      NBA=NAA+NC*NR-1                                                    LIT04920
      IF(XC.EQ.XZR) GO TO 451                                            LIT04930
      CALL MFIND(XC,&5)                                                  LIT04940
      NAB=NX                                                             LIT04950
      NBB=NAB+NC*NR-1                                                    LIT04960
      IF(XD.EQ.XZR) GO TO 451                                            LIT04970
      CALL MFIND(XD,&5)                                                  LIT04980
      NAC=NX                                                             LIT04990
      NBC=NAC+NC*NR-1                                                    LIT05000
  451 CALL PLOT(NA,NB,NAA,NAB,NAC,NBA,NBB,NBC,INR)                       LIT05010
      IF(NNC) 455,455,454                                                LIT05020
  454 IF(INR) 456,456,457                                                LIT05030
  456 DO 458 JJ=1,NNC                                                    LIT05040
  458 READ(5,105) HED                                                    LIT05050
      GO TO 5                                                            LIT05060
  457 DO 459 JJ=1,NNC                                                    LIT05070
      READ(5,105) HED                                                    LIT05080
  459 WRITE(8,110) HED                                                   LIT05090
  455 GO TO 5                                                            LIT05100
C                                                                        LIT05110
C       INTEGRATION OPERATION                                            LIT05120
C                                                                        LIT05130
  460 CALL MFIND(XA,&5)                                                  LIT05140
      NA=NX                                                              LIT05150
      INR=NNR                                                            LIT05160
      CALL ITGRAL(NA,INR)                                                LIT05170
      GO TO 5                                                            LIT05180
C                                                                        LIT05190
C       CONTUR OPERATION                                                 LIT05200
C                                                                        LIT05210
  470 NOC=NC                                                             LIT05220
      IF(NNR.EQ.0) NNR=1                                                 LIT05230
      IF(NNC.EQ.0) NNC=1                                                 LIT05240
```

```
      NAR=NNR                                                          LIT05250
      NAC=NNC                                                          LIT05260
      IF(NOC.LT.1) GO TO 474                                           LIT05270
      DO 471 I=1,NOC                                                   LIT05280
      READ(5,105) HED                                                  LIT05290
      GO TO (471,472),NAC                                              LIT05300
  472 WRITE(8,110) HED                                                 LIT05310
  471 CONTINUE                                                         LIT05320
  474 CALL CONTUR(XA,XB,NAR,NAC,NOC)                                   LIT05330
      GO TO 5                                                          LIT05340
C                                                                      LIT05350
CC     POLYNOMINAL FIT OPERATION                                       LIT05360
C                                                                      LIT05370
  480 CALL POLFIT(XA,XB,&5)                                            LIT05380
      GO TO 5                                                          LIT05390
C                                                                      LIT05400
CC    PUNCH OPERATION                                                  LIT05410
C                                                                      LIT05420
  490 READ(5,105) FMT                                                  LIT05430
      IF(NR.EQ.0) GO TO 491                                            LIT05440
      DO 492 J=1,NR                                                    LIT05450
      READ(5,105) HED                                                  LIT05460
  492 WRITE(7,105) HED                                                 LIT05470
  491 CALL MFIND(XA,&5)                                                LIT05480
      NA=NX                                                            LIT05490
      NB=NA-1+NR*NC                                                    LIT05500
      WRITE(7,FMT) (A(I),I=NA,NB)                                      LIT05510
      GO TO 5                                                          LIT05520
   99 FORMAT (1H1 )                                                    LIT05530
  100 FORMAT(5X,5A6)                                                   LIT05540
  101 FORMAT(5A6,4I6,2F6.0)                                            LIT05550
  102 FORMAT (1I6,6H ROWS, 1I6, 8H COLUMNS )                           LIT05560
  103 FORMAT (9H  SCALAR= 1PD15.7)                                     LIT05570
  104 FORMAT (12H  ROW NUMBER I4,18H,    COLUMN NUMBER I4)             LIT05580
  105 FORMAT(10A8)                                                     LIT05590
  106 FORMAT (11H  TAPE UNIT  I3)                                      LIT05600
  107 FORMAT(1I6,2F12.5)                                               LIT05610
  108 FORMAT (1I6,1F15.5,1PD18.7)                                      LIT05620
  109 FORMAT(1H0)                                                      LIT05630
  110 FORMAT(2X,10A8)                                                  LIT05640
  111 FORMAT(10X,1A6)                                                  LIT05650
      END                                                              LIT05660
```

```
      SUBROUTINE APRINT( A ,NR,NC,NNR)                                  LIT05670
      IMPLICIT REAL*8(A-H,O-Z)                                          LIT05680
      DIMENSION A(1),NCOL(8)                                            LIT05690
      DOUBLE PRECISION A                                                LIT05700
C                                                                       LIT05710
CCC   PRINT OPERATION                                                   LIT05720
C                                                                       LIT05730
      IF(NNR.EQ.1) GO TO 60                                             LIT05740
      DO 50 M=1,NC,8                                                    LIT05750
      NN=NC-M                                                           LIT05760
      IF (NN-7) 40,40,35                                                LIT05770
   35 NN=7                                                              LIT05780
   40 MM=NN+1                                                           LIT05790
      DO 45 N=1,MM                                                      LIT05800
   45 NCOL(N)=M-1+N                                                     LIT05810
      WRITE(6,101) (NCOL(N),N=1,MM)                                     LIT05820
      DO 50 N=1,NR                                                      LIT05830
      NL=M+(N-1)*NC                                                     LIT05840
      NH=NL+NN                                                          LIT05850
   50 WRITE(6,100) (N,(A(I),I=NL,NH))                                   LIT05860
      RETURN                                                            LIT05870
   60 DO 61 M=1,NC,8                                                    LIT05880
      NN=NC-M                                                           LIT05890
      IF(NN-7) 63,63,62                                                 LIT05900
   62 NN=7                                                              LIT05910
   63 MM=NN+1                                                           LIT05920
      DO 64 N=1,MM                                                      LIT05930
   64 NCOL(N)=M-1+N                                                     LIT05940
      WRITE(8,101) (NCOL(N),N=1,MM)                                     LIT05950
      DO 61 N=1,NR                                                      LIT05960
      NL=M+(N-1)*NC                                                     LIT05970
      NH=NL+NN                                                          LIT05980
   61 WRITE(8,100) (N,(A(I),I=NL,NH))                                   LIT05990
      WRITE(8,102)                                                      LIT06000
      RETURN                                                            LIT06010
  100 FORMAT(2X,1I6,2X,8(1PD13.6     ))                                 LIT06020
  101 FORMAT(1H0,2X,8I13)                                               LIT06030
  102 FORMAT(1H0)                                                       LIT06040
  103 FORMAT(T10,1A6)                                                   LIT06050
      END                                                               LIT06060

      SUBROUTINE ERRER(N,*)                                             LIT06070
      IMPLICIT REAL*8(A-H,O-Z)                                          LIT06080
      REAL*8 NSTART,NOPER                                               LIT06090
      COMMON       XNAME(100),A(10000),W1(80),W2(80),W3(80),W4(80)      LIT06100
     1            ,NSIZE,NUM,NX,NR,NC,NNR,NNC,NDUM,NROW(100),NCOL(100) LIT06110
     2,NN(100),NW1(80)                                                  LIT06120
```

```
      GO TO (1,2,3,4,5,6,7,8,9,10,11),N                                 LIT06130
    1 WRITE(6,101)                                                      LIT06140
      GO TO 100                                                         LIT06150
    2 WRITE(6,102)                                                      LIT06160
      GO TO 100                                                         LIT06170
    3 WRITE(6,103)                                                      LIT06180
      GO TO 100                                                         LIT06190
    4 WRITE(6,104)                                                      LIT06200
      GO TO 100                                                         LIT06210
    5 WRITE(6,105)                                                      LIT06220
      GO TO 100                                                         LIT06230
    6 WRITE(6,106)                                                      LIT06240
      GO TO 100                                                         LIT06250
    7 WRITE(6,107)                                                      LIT06260
      GO TO 100                                                         LIT06270
    8 WRITE(6,108)                                                      LIT06280
      GO TO 100                                                         LIT06290
    9 WRITE(6,109)                                                      LIT06300
      GO TO 100                                                         LIT06310
                                                                        LIT06320
   10 WRITE(6,110)                                                      LIT06330
      GO TO 100                                                         LIT06340
   11 WRITE(6,111)                                                      LIT06350
  100 RETURN 1                                                          LIT06360
   50 FORMAT (1A6)                                                      LIT06370
   99 FORMAT(1H1,4X,6H START)                                           LIT06380
  101 FORMAT (27H MATRICES INCOMPATIBLE       )                         LIT06390
  102 FORMAT (27H MATRIX UNDEFINED            )                         LIT06400
  103 FORMAT (27H OPERATION UNDEFINED         )                         LIT06410
  104 FORMAT (27H MATRIX PREVIOUSLY DEFINED   )                         LIT06420
  105 FORMAT (27H STORAGE EXCEEDED            )                         LIT06430
  106 FORMAT (27H OVER 100 MATRICES IN CORE   )                         LIT06440
  107 FORMAT(27H ERROR IN EIGEN SUBROUTINE     )                        LIT06450
  108 FORMAT(27H ERROR IN LOAD OPERATION     )                          LIT06460
  109 FORMAT (27H OPERATION NOT AVAILABLE    )                         LIT06470
  110 FORMAT (27H ERROR IN READ OPERATION    )                         LIT06480
  111 FORMAT (27H ERROR IN WRITE OPERATION   )                         LIT06490
      END                                                               LIT06500

      SUBROUTINE FORMK(A)                                               LIT06510
      IMPLICIT REAL*8(A-H,O-Z)                                          LIT06520
      DIMENSION A(1)                                                    LIT06530
      DOUBLE PRECISION A                                                LIT06540
      READ(5,100) XI,XA,XL,XE                                           LIT06550
      WRITE(6,200) XI,XA,XL,XE                                          LIT06560
      B=14.4*XI/(XA*XL**2)                                              LIT06570
      S=2.*XE*XI/((1.+2.*B)*XL)                                         LIT06580
```

```
      A(1)=S*(2.+B)                                                          LIT06590
      A(2)=S*(1.-B)                                                          LIT06600
      A(3)=A(2)                                                              LIT06610
      A(4)=A(1)                                                              LIT06620
      RETURN                                                                 LIT06630
  100 FORMAT (4F12.1)                                                        LIT06640
  200 FORMAT (3H I=F12.1,5H,  A=F12.1,5H,  L=F12.1,5H,  E=F12.1)             LIT06650
      END                                                                    LIT06660

      SUBROUTINE LOAD( A ,NR,NC,NFMT,SCAL1,*)                                LIT06670
      IMPLICIT REAL*8(A-H,O-Z)                                               LIT06680
      DIMENSION A(1)                                                         LIT06690
      DOUBLE PRECISION A                                                     LIT06700
C                                                                            LIT06710
CC    LOAD OPERATION                                                         LIT06720
C                                                                            LIT06730
      IF(NFMT.GT.4) CALL ERRER(8,&5)                                         LIT06740
      NS=NR*NC                                                               LIT06750
      IF(NFMT.EQ.0) NFMT=1                                                   LIT06760
      IF(SCAL1.EQ.1.0)GO TO 14                                               LIT06770
      GO TO (10,11,12,13),NFMT                                               LIT06780
   10 READ(5,100) (A(I),I=1,NS)                                              LIT06790
      GO TO 15                                                               LIT06800
   11 READ(5,101) (A(I),I=1,NS)                                              LIT06810
      GO TO 15                                                               LIT06820
   12 READ(5,102) (A(I),I=1,NS)                                              LIT06830
   13 READ(5,103) (A(I),I=1,NS)                                              LIT06840
      GO TO 15                                                               LIT06850
   14 GO TO(20,21,22,23),NFMT                                                LIT06860
   20 READ(4,100) (A(I),I=1,NS)                                              LIT06870
      GO TO 15                                                               LIT06880
   21 READ(4,101) (A(I),I=1,NS)                                              LIT06890
      GO TO 15                                                               LIT06900
   22 READ(4,102) (A(I),I=1,NS)                                              LIT06910
      GO TO 15                                                               LIT06920
   23 READ(4,103) (A(I),I=1,NS)                                              LIT06930
   15 RETURN                                                                 LIT06940
    5 RETURN 1                                                               LIT06950
  100 FORMAT (12F6.0)                                                        LIT06960
  101 FORMAT(6F12.0)                                                         LIT06970
  102 FORMAT(4F18.0)                                                         LIT06980
  103 FORMAT(3F24.0)                                                         LIT06990
      END                                                                    LIT07000
```

```
      SUBROUTINE MFIND(MM,*)                                                    LIT07010
      IMPLICIT REAL*8(A-H,O-Z)                                                  LIT07020
      COMMON       NAME(100),A(10000),W1(80),W2(80),W3(80),W4(80)               LIT07030
     1            ,NSIZE,NUM,NX,NR,NC,NNR,NNC,NDUM,NROW(100),NCOL(100)         LIT07040
     2,NN(100),NW1(80)                                                          LIT07050
C                                                                               LIT07060
CCC   SUBROUTINE TO FIND LOCATION AND SIZE OF MATRIX XX                         LIT07070
C                                                                               LIT07080
      REAL*8 NAME,MM                                                            LIT07090
      I=1                                                                       LIT07100
   15 IF((NUM-I).LT.0) CALL ERRER(2,&5)                                         LIT07110
   10 IF ( NAME(I)-MM) 20,30,20                                                 LIT07120
   20 I=I+1                                                                     LIT07130
      GO TO 15                                                                  LIT07140
   30 NR=NROW(I)                                                                LIT07150
      NC=NCOL(I)                                                                LIT07160
      NX=NN(I)                                                                  LIT07170
      RETURN                                                                    LIT07180
    5 RETURN 1                                                                  LIT07190
      END                                                                       LIT07200

      SUBROUTINE DELETE(MM,*)                                                   LIT07210
      IMPLICIT REAL*8(A-H,O-Z)                                                  LIT07220
C                                                                               LIT07230
CCC    SUBROUTINE TO DELETE MATRIX MM                                           LIT07240
C                                                                               LIT07250
      REAL*8 NAME,MM                                                            LIT07260
      COMMON       NAME(100),A(10000),W1(80),W2(80),W3(80),W4(80)               LIT07270
     1            ,NSIZE,NUM,NX,NR,NC,NNR,NNC,NDUM,NROW(100),NCOL(100)         LIT07280
     2,NN(100),NW1(80)                                                          LIT07290
      I=1                                                                       LIT07300
   15 IF (NUM-I) 40,10,10                                                       LIT07310
   40 CALL ERRER(2,&5)                                                          LIT07320
   10 IF ( NAME(I)-MM) 20,30,20                                                 LIT07330
   20 I=I+1                                                                     LIT07340
      GO TO 15                                                                  LIT07350
   30 NX=NN(I)                                                                  LIT07360
      NUM=NUM-1                                                                 LIT07370
      NS=NROW(I)*NCOL(I)                                                        LIT07380
      NSIZE=NSIZE-NS                                                            LIT07390
      DO 50 J=I,NUM                                                             LIT07400
      NAME(J)=NAME(J+1)                                                         LIT07410
      NROW(J)=NROW(J+1)                                                         LIT07420
      NCOL(J)=NCOL(J+1)                                                         LIT07430
   50 NN(J)=NN(J+1)-NS                                                          LIT07440
      DO 60 J=NX,NSIZE                                                          LIT07450
      I=J+NS                                                                    LIT07460
```

```
   60 A(J)=A(I)                                                          LIT07470
        RETURN                                                           LIT07480
    5 RETURN 1                                                           LIT07490
      END                                                                LIT07500

      SUBROUTINE MULT(NRA,A,NCA,B,NCB,C)                                 LIT07510
      IMPLICIT REAL*8(A-H,O-Z)                                           LIT07520
      DIMENSION A(1),B(1),C(1)                                           LIT07530
      DOUBLE PRECISION A,B,C                                             LIT07540
C                                                                        LIT07550
CC      MATRIX MULTIPLICATION                                            LIT07560
C                                                                        LIT07570
      K=1                                                                LIT07580
      DO 200 I=1,NRA                                                     LIT07590
      NN=(I-1)*NCA+1                                                     LIT07600
      NH=NN-1+NCA                                                        LIT07610
      DO 200 J=1,NCB                                                     LIT07620
      MM=J                                                               LIT07630
      C(K)=0.0D0                                                         LIT07640
      DO 100 L=NN,NH                                                     LIT07650
      C(K)=C(K)+A(L)*B(MM)                                               LIT07660
  100 MM=MM+NCB                                                          LIT07670
  200 K=K+1                                                              LIT07680
      RETURN                                                             LIT07690
      END                                                                LIT07700

      SUBROUTINE TRANS(A,B,NR,NC)                                        LIT07710
      IMPLICIT REAL*8(A-H,O-Z)                                           LIT07720
      DIMENSION A(1),B(1)                                                LIT07730
      DOUBLE PRECISION A,B                                               LIT07740
C                                                                        LIT07750
CC      MATRIX TRANSPOSE                                                 LIT07760
C                                                                        LIT07770
      K=1                                                                LIT07780
      DO 100 I=1,NC                                                      LIT07790
      L=I                                                                LIT07800
      DO 100 J=1,NR                                                      LIT07810
      B(K)=A(L)                                                          LIT07820
      L=L+NC                                                             LIT07830
  100 K=K+1                                                              LIT07840
      RETURN                                                             LIT07850
      END                                                                LIT07860
```

```
      SUBROUTINE INVERT(A,C,M,N)                                        LIT07870
      IMPLICIT REAL*8(A-H,O-Z)                                          LIT07380
      DIMENSION A(1),C(1),M(1)                                          LIT07890
      DOUBLE PRECISION A,C                                              LIT07900
C                                                                       LIT07910
CC         GENERAL MATRIX INVERSION SUBROUTINE                          LIT07920
C                                                                       LIT07930
      DO 90 I=1,N                                                       LIT07940
   90 M(I)=-I                                                           LIT07950
      DO 140 I=1,N                                                      LIT07960
C                                                                       LIT07970
CC    LOCATE LARGEST ELEMENT                                            LIT07980
C                                                                       LIT07990
      D=0.0D0                                                           LIT08000
      DO 112 L=1,N                                                      LIT08010
      IF (M(L)) 100,100,112                                             LIT08020
  100 J=L                                                               LIT08030
      DO 110 K=1,N                                                      LIT08040
      IF (M(K)) 103,103,108                                             LIT08050
  103 IF (DABS(D)-DABS(A(J))) 105,105,108                               LIT08060
  105 LD=L                                                              LIT08070
      KD=K                                                              LIT08080
      D=A(J)                                                            LIT08090
  108 J=J+N                                                             LIT08100
  110 CONTINUE                                                          LIT08110
  112 CONTINUE                                                          LIT08120
C                                                                       LIT08130
CC    INTERCHANGE COLUMNS                                               LIT08140
C                                                                       LIT08150
      TEMP=-M(LD)                                                       LIT08160
      M(LD)=M(KD)                                                       LIT08170
      M(KD)=TEMP                                                        LIT08180
      L=LD                                                              LIT08190
      K=KD                                                              LIT08200
      DO 114 J=1,N                                                      LIT08210
      C(J)=A(L)                                                         LIT08220
      A(L)=A(K)                                                         LIT08230
      A(K)=C(J)                                                         LIT08240
      L=L+N                                                             LIT08250
  114 K=K+N                                                             LIT08260
C                                                                       LIT08270
CC    DIVIDE ROW BY LARGEST ELEMENT                                     LIT08280
C                                                                       LIT08290
      NR=(KD-1)*N+1                                                     LIT08300
      NH=NR+N-1                                                         LIT08310
      DO 115 K=NR,NH                                                    LIT08320
  115 A(K)=-A(K)/D                                                      LIT08330
C                                                                       LIT08340
```

```
C       REDUCE REMAINING ROWS AND COLUMNS                                LIT08350
C                                                                        LIT08360
        L=1                                                              LIT08370
        DO 135 J=1,N                                                     LIT08380
        IF (J-KD) 130,125,130                                            LIT08390
  125   L=L+N                                                            LIT08400
        GO TO 135                                                        LIT08410
  130   DO 134 K=NR,NH                                                   LIT08420
        A(L)=A(L)+C(J)*A(K)                                              LIT08430
  134   L=L+1                                                            LIT08440
  135   CONTINUE                                                         LIT08450
C                                                                        LIT08460
CC      REDUCE COLUMN                                                    LIT08470
C                                                                        LIT08480
        C(KD)=1.0D0                                                      LIT08490
        J=KD                                                             LIT08500
        DO 140 K=1,N                                                     LIT08510
        A(J)=C(K)/D                                                      LIT08520
  140   J=J+N                                                            LIT08530
C                                                                        LIT08540
CC      INTERCHANGE ROWS                                                 LIT08550
C                                                                        LIT08560
        DO 200 I=1,N                                                     LIT08570
        L=0                                                              LIT08580
  150   L=L+1                                                            LIT08590
        IF(M(L)-I) 150,160,150                                           LIT08600
  160   K=(L-1)*N+1                                                      LIT08610
        J=(I-1)*N+1                                                      LIT08620
        M(L)=M(I)                                                        LIT08630
        M(I)=I                                                           LIT08640
        DO 200 LL=1,N                                                    LIT08650
        TEMP=A(K)                                                        LIT08660
        A(K)=A(J)                                                        LIT08670
        A(J)=TEMP                                                        LIT08680
        J=J+1                                                            LIT08690
  200   K=K+1                                                            LIT08700
        RETURN                                                           LIT08710
        END                                                              LIT08720

        SUBROUTINE SYMINV(A,N,B,C)                                       LIT08730
        IMPLICIT REAL*8(A-H,O-Z)                                         LIT08740
        DIMENSION A(1),B(1),C(1)                                         LIT08750
        DOUBLE PRECISION A,B,C                                           LIT08760
C                                                                        LIT08770
CC       SYMMETRICAL MATRIX INVERSION                                    LIT08780
C                                                                        LIT08790
        LP=N                                                             LIT08800
```

```
      DO 10  I=2,LP                                                     LIT08810
      DO 10  J=I,LP                                                     LIT08820
      ICOL=J+LP*(I-2)                                                   LIT08830
      IROW=I+(J-1)*LP-1                                                 LIT08840
      IF(A(ICOL).NE.A(IROW))  WRITE(6,1000)                             LIT08850
      A(ICOL)=0.5D0*(A(ICOL)+A(IROW))                                   LIT08860
   10 A(IROW)=A(ICOL)                                                   LIT08870
 1000 FORMAT(/,54H **************************************************LIT08880
     1       /,54H WARNING THE INPUT MATRIX TO SYMINV WAS NOT SYMMETRIC LIT08890
     2     /,54H ************************************************** )  LIT08900
      DO 140 I=1,N                                                      LIT08910
      NR=(I-1)*N                                                        LIT08920
      DO 100 J=1,N                                                      LIT08930
      K=NR+J                                                            LIT08940
  100 B(J)=A(K)                                                         LIT08950
      D=B(I)                                                            LIT08960
      DO 110 J=1,N                                                      LIT08970
  110 C(J)=-B(J)/D                                                      LIT08980
      L=1                                                               LIT08990
      DO 130 J=1,N                                                      LIT09000
      M=L                                                               LIT09010
      DO 120 K=J,N                                                      LIT09020
      A(L)=A(L)+B(J)*C(K)                                               LIT09030
      A(M)=A(L)                                                         LIT09040
      M=M+N                                                             LIT09050
  120 L=L+1                                                             LIT09060
  130 L=L+J                                                             LIT09070
      C(I)=-1.0D0/D                                                     LIT09080
      M=I                                                               LIT09090
      DO 140 J=1,N                                                      LIT09100
      K=NR+J                                                            LIT09110
      A(K)=C(J)                                                         LIT09120
      A(M)=C(J)                                                         LIT09130
  140 M=M+N                                                             LIT09140
      NS=N*N                                                            LIT09150
      DO 150 J=1,NS                                                     LIT09160
  150 A(J)=-A(J)                                                        LIT09170
      RETURN                                                            LIT09180
      END                                                               LIT09190


      SUBROUTINE STOSM(A,B,NRA,NCA,NRB,NCB,NR,NC,NTAG,*)                LIT09200
      IMPLICIT REAL*8(A-H,O-Z)                                          LIT09210
      DIMENSION A(1),B(1)                                               LIT09220
      DOUBLE PRECISION A,B                                              LIT09230
C                                                                       LIT09240
CC     SUBROUTINE TO STORE OR REMOVE A SUBMATRIX                        LIT09250
C                                                                       LIT09260
```

```
      IF (NRA+1-NR-NRB) 60,50,50                                        LIT09270
   50 IF (NCA+1-NC-NCB) 60,70,70                                        LIT09280
   60 CALL ERRER(1,&5)                                                  LIT09290
   70 DO 100 I=1,NRB                                                    LIT09300
      K=(NC-1)+(NR+I-2)*NCA                                             LIT09310
      L=(I-1)*NCB                                                       LIT09320
      DO 100 J=1,NCB                                                    LIT09330
      N=K+J                                                             LIT09340
      M=L+J                                                             LIT09350
      IF (NTAG) 75,90,80                                                LIT09360
   75 A(N)=A(N)+B(M)                                                    LIT09370
      GO TO 100                                                         LIT09380
   80 A(N)=B(M)                                                         LIT09390
      GO TO 100                                                         LIT09400
   90 B(M)=A(N)                                                         LIT09410
  100 CONTINUE                                                          LIT09420
      RETURN                                                            LIT09430
    5 RETURN 1                                                          LIT09440
      END                                                               LIT09450

      SUBROUTINE RESPON(W,XM,P,X,NM,NT,L,DAMP,DT,NTAG)                  LIT09460
      IMPLICIT REAL*8(A-H,O-Z)                                          LIT09470
      DIMENSION W(1),XM(1),P(1),X(1)                                    LIT09480
      DOUBLE PRECISION W,XM,P,X,DAMP,DT                                 LIT09490
C                                                                       LIT09500
CC      RESPONSE PROGRAM                                                LIT09510
C                                                                       LIT09520
      K=1                                                               LIT09530
      C1=DT/2.0D0                                                       LIT09540
      C2=C1*DT/3.0D0                                                    LIT09550
      C3=C2*2.0D0                                                       LIT09560
      DO 160 N=1,NM                                                     LIT09570
      NOUT=NT+1                                                         LIT09580
      C4=W(N)**2                                                        LIT09590
      C5=   DAMP*W(N)*2.0D0                                             LIT09600
      F=   C1*C5+C2*C4+1.0D0                                            LIT09610
      DISP=0.0D0                                                        LIT09620
      VEL=0.0D0                                                         LIT09630
      IL=L*(N-1)*NTAG+1                                                 LIT09640
      ACEL=P(IL)*XM(N)                                                  LIT09650
      IL=IL+1                                                           LIT09660
      IH=IL+L-2                                                         LIT09670
      DO 160 I=IL,IH                                                    LIT09680
      A=VEL+C1*ACEL                                                     LIT09690
      B=DISP+DT*VEL+C3*ACEL                                             LIT09700
      ACEL=(P(I)*XM(N)-C5*A-C4*B)/F                                     LIT09710
      VEL=A+C1*ACEL                                                     LIT09720
```

```
      DISP=B+C2*ACEL                                                    LIT09730
      IF(NOUT-I) 160,150,160                                            LIT09740
  150 X(K)=DISP                                                         LIT09750
      K=K+1                                                             LIT09760
      NOUT=NOUT+NT                                                      LIT09770
  160 CONTINUE                                                          LIT09780
      RETURN                                                            LIT09790
      END                                                               LIT09800

      SUBROUTINE EIG(R,XM,V,E,NEV,M,N2,NM)                              LIT09810
      IMPLICIT REAL*8(A-H,O-Z)                                          LIT09820
      DIMENSION R(1),XM(1),V(1),E(1)                                    LIT09830
      DOUBLE PRECISION R,XM,V,E                                         LIT09840
      LP=NM                                                             LIT09850
      IF(NM.EQ.1) RETURN                                                LIT09860
      NVEC=IABS(M)                                                      LIT09870
    1 DO 2 I=1,LP                                                       LIT09880
    2 XM(I)=1.0D0/(DSQRT(XM(I)))                                        LIT09890
      DO 3 I=1,LP                                                       LIT09900
      DO 3 J=1,LP                                                       LIT09910
      JJ=I+(J-1)*NM                                                     LIT09920
    3 R(JJ)=XM(I)*R(JJ)*XM(J)                                           LIT09930
      DO 104 I=2,LP                                                     LIT09940
      DO 104 J=I,LP                                                     LIT09950
      ICOL=J+LP*(I-2)                                                   LIT09960
      IROW=I+(J-1)*LP-1                                                 LIT09970
      IF(R(ICOL).NE.R(IROW))  WRITE(6,1000)                             LIT09980
      R(ICOL)=0.5D0*(R(ICOL)+R(IROW))                                   LIT09990
  104 R(IROW)=R(ICOL)                                                   LIT10000
 1000 FORMAT(/,54H **************************************************LIT10010
     1       /,54H WARNING THE INPUT MATRIX TO EIGEN WAS NOT SYMMETRIC  LIT10020
     2    /,54H ************************************************** )   LIT10030
      CALL JACVAT(R,NM,1,E,V,NM)                                        LIT10040
      NEL=NVEC*NM                                                       LIT10050
      DO 400 J=1,NVEC                                                   LIT10060
      ANORM=0.0D0                                                       LIT10070
      NL=1+(J-1)*NM                                                     LIT10080
      NH=NL+NM-1                                                        LIT10090
      DO 200 I=NL,NH                                                    LIT10100
  200 ANORM=ANORM+V(I)*V(I)                                             LIT10110
      ANORM=DSQRT(ANORM)                                                LIT10120
      DO 300 I=NL,NH                                                    LIT10130
  300 V(I)=V(I)/ANORM                                                   LIT10140
  400 CONTINUE                                                          LIT10150
C                                                                       LIT10160
CC    MODIFY VECTORS                                                    LIT10170
C                                                                       LIT10180
```

```
      DO 500 I=1,LP                                                     LIT10190
      DO 500 J=1,NVEC                                                   LIT10200
      JJ=I+(J-1)*NM                                                     LIT10210
      IF(N2.EQ.1) GO TO 450                                             LIT10220
      V(JJ)=V(JJ)*XM(I)                                                 LIT10230
      GO TO 500                                                         LIT10240
  450 V(JJ)=V(JJ)/XM(I)                                                 LIT10250
  500 CONTINUE                                                          LIT10260
      IF(M.GT.0) RETURN                                                 LIT10270
      NLIM=NEV/2                                                        LIT10280
      DO 600 I=1,NLIM                                                   LIT10290
      ATEMP=E(I)                                                        LIT10300
      II=NEV-I+1                                                        LIT10310
      E(I)=E(II)                                                        LIT10320
  600 E(II)=ATEMP                                                       LIT10330
      NLIM=NVEC/2                                                       LIT10340
      DO 700 I=1,NLIM                                                   LIT10350
      DO 700 J=1,NM                                                     LIT10360
      JJ=J+(I-1)*NM                                                     LIT10370
      JJJ=NEL-NM*I+J                                                    LIT10380
      ATEMP=V(JJ)                                                       LIT10390
      V(JJ)=V(JJJ)                                                      LIT10400
  700 V(JJJ)=ATEMP                                                      LIT10410
      RETURN                                                            LIT10420
      END                                                               LIT10430

      SUBROUTINE JACVAT(A,N,NOYES,EIVU,EIVR,NDIM)                       LIT10440
      IMPLICIT REAL*8(A-H,O-Z)                                          LIT10450
      DIMENSION A(NDIM,NDIM),EIVU(NDIM),EIVR(NDIM,NDIM)                 LIT10460
      IF(N-1)20,23,21                                                   LIT10470
   20 PRINT 22,N                                                        LIT10480
   22 FORMAT(4H N= ,I3,68H IS TOO SMALL.  LIMIT IS 1.  RETURN TO CALLINGLIT10490
     1 ROUTINE FROM JACVAT. )                                           LIT10500
      RETURN                                                            LIT10510
   23 PRINT 24, A(1,1)                                                  LIT10520
   24 FORMAT (24H IN JACVAT , MATRIX A = ,E14.6)                        LIT10530
      RETURN                                                            LIT10540
   21 IF(N-160)1,1,3                                                    LIT10550
    3 PRINT 2,N                                                         LIT10560
    2 FORMAT(3H N=,I5,70H IS TOO LARGE.  LIMIT IS 160.  RETURN TO CALLI-LIT10570
     1NG ROUTINE FROM JACVAT. )                                         LIT10580
      RETURN                                                            LIT10590
    1 IF(NOYES)99,102,99                                                LIT10600
   99 CONTINUE                                                          LIT10610
      DO 101 J=1,N                                                      LIT10620
      DO 100 I=1,N                                                      LIT10630
  100 EIVR(I,J)=0.0                                                     LIT10640
```

```
101 EIVR(J,J)=1.0                                                       LIT10650
102 ATOP=0.                                                             LIT10660
    DO 112 J=1,N                                                        LIT10670
    DO 111 I=1,J                                                        LIT10680
    IF(A(I,J)-A(J,I))90,103,90                                          LIT10690
 90 PRINT 106,N,N                                                       LIT10700
106 FORMAT(14H IN JACVAT (A(,I3,1H,,I3,3H)),)                           LIT10710
    PRINT 108,I,J,J,I                                                   LIT10720
108 FORMAT(3H A(,I3,1H,,I3,10H)  AND  A(,I3,1H,,I3,54H) WERE UNEQUAL,   LIT10730
   1SO THEY WERE REPLACED WITH THEIR MEAN )                             LIT10740
    A(I,J)=.5*(A(I,J)+A(J,I))                                           LIT10750
    A(J,I)=A(I,J)                                                       LIT10760
103 CONTINUE                                                            LIT10770
    IF(ATOP-DABS(A(I,J)))104,111,111                                    LIT10780
104 ATOP=DABS(A(I,J))                                                   LIT10790
111 CONTINUE                                                            LIT10800
112 EIVU(J)=A(J,J)                                                      LIT10810
    IF(ATOP)109,109,113                                                 LIT10820
109 PRINT 110                                                           LIT10830
110 FORMAT(26H IN JACVAT, MATRIX A  = 0 )                               LIT10840
    RETURN                                                              LIT10850
113 AVGF=DFLOAT(N*(N-1))*.55                                            LIT10860
    D=0.0                                                               LIT10870
    DO 114 JJ=2,N                                                       LIT10880
    DO 114 II=2,JJ                                                      LIT10890
    S=A(II-1,JJ)/ATOP                                                   LIT10900
114 D=S*S+D                                                             LIT10910
    DSTOP=(1.D-08)*D                                                    LIT10920
    THRSH =DSQRT (D/AVGF)*ATOP                                          LIT10930
115 IFLAG=0                                                             LIT10940
    DO 130 JCOL=2,N                                                     LIT10950
    JCOL1=JCOL-1                                                        LIT10960
    DO 130 IROW=1,JCOL1                                                 LIT10970
    AIJ=A(IROW,JCOL)                                                    LIT10980
    IF(DABS(AIJ)-THRSH)130,130,117                                      LIT10990
117 AII=A(IROW,IROW)                                                    LIT11000
    AJJ=A(JCOL,JCOL)                                                    LIT11010
    S=AJJ-AII                                                           LIT11020
    IF(DABS(AIJ)-1.D-09*DABS(S))130,130,118                             LIT11030
118 IFLAG=1                                                             LIT11040
    IF(1.D-10*DABS(AIJ)-DABS(S))116,119,119                             LIT11050
119 S=.707106781                                                        LIT11060
    C=S                                                                 LIT11070
    GO TO 120                                                           LIT11080
116 T=AIJ/S                                                             LIT11090
    S=0.25/DSQRT(0.25+T*T)                                              LIT11100
    C=DSQRT(0.5+S)                                                      LIT11110
    S=2.*T*S/C                                                          LIT11120
```

```
  120 DO 121 I=1,IROW                                                    LIT11130
      T=A(I,IROW)                                                        LIT11140
      U=A(I,JCOL)                                                        LIT11150
      A(I,IROW)=C*T-S*U                                                  LIT11160
  121 A(I,JCOL)=S*T+C*U                                                  LIT11170
      I2=IROW+2                                                          LIT11180
      IF(I2-JCOL)127,127,123                                             LIT11190
  127 CONTINUE                                                           LIT11200
      DO 122 I=I2,JCOL                                                   LIT11210
      T=A(I-1,JCOL)                                                      LIT11220
      U=A(IROW,I-1)                                                      LIT11230
      A(I-1,JCOL)=S*U+C*T                                                LIT11240
  122 A(IROW,I-1)=C*U-S*T                                                LIT11250
  123 A(JCOL,JCOL)=S*AIJ+C*AJJ                                           LIT11260
      A(IROW,IROW)=C*A(IROW,IROW)-S*(C*AIJ-S*AJJ)                        LIT11270
      DO 124 J=JCOL,N                                                    LIT11280
      T=A(IROW,J)                                                        LIT11290
      U=A(JCOL,J)                                                        LIT11300
      A(IROW,J)=C*T-S*U                                                  LIT11310
  124 A(JCOL,J)=S*T+C*U                                                  LIT11320
      IF(NOYES)131,126,131                                               LIT11330
  131 CONTINUE                                                           LIT11340
      DO 125 I=1,N                                                       LIT11350
      T=EIVR(I,IROW)                                                     LIT11360
      EIVR(I,IROW)=C*T-EIVR(I,JCOL)*S                                    LIT11370
  125 EIVR(I,JCOL)=S*T+EIVR(I,JCOL)*C                                    LIT11380
  126 CONTINUE                                                           LIT11390
      S=AIJ/ATOP                                                         LIT11400
      D=D-S*S                                                            LIT11410
      IF(D-DSTOP)1260,129,129                                            LIT11420
 1260 D=0.                                                               LIT11430
      DO 128 JJ=2,N                                                      LIT11440
      DO 128 II=2,JJ                                                     LIT11450
      S=A(II-1,JJ)/ATOP                                                  LIT11460
  128 D=S*S+D                                                            LIT11470
      DSTOP=(1.D-08)*D                                                   LIT11480
  129 THRSH=DSQRT(D/AVGF)*ATOP                                           LIT11490
  130 CONTINUE                                                           LIT11500
      IF(IFLAG)115,134,115                                               LIT11510
  134 T=A(1,1)                                                           LIT11520
      A(1,1)=EIVU(1)                                                     LIT11530
      EIVU(1)=T                                                          LIT11540
      DO 132 J=2,N                                                       LIT11550
      T=A(J,J)                                                           LIT11560
      A(J,J)=EIVU(J)                                                     LIT11570
      EIVU(J)=T                                                          LIT11580
      DO 132 I=2,J                                                       LIT11590
  132 A(I-1,J)=A(J,I-1)                                                  LIT11600
```

```
C  ORDER VECTORS AND VALUES                                                    LIT11610
      DO 200 I=1,N                                                            LIT11620
       DO 200 J=I,N                                                           LIT11630
      IF(EIVU(I).GE.EIVU(J)) GO TO 200                                        LIT11640
      TEMP=EIVU(I)                                                            LIT11650
      EIVU(I)=EIVU(J)                                                         LIT11660
      EIVU(J)=TEMP                                                            LIT11670
      DO 195 K=1,N                                                            LIT11680
      TEMP=EIVR(K,I)                                                          LIT11690
      EIVR(K,I)=EIVR(K,J)                                                     LIT11700
  195 EIVR(K,J)=TEMP                                                          LIT11710
  200 CONTINUE                                                                LIT11720
  133 RETURN                                                                  LIT11730
      END                                                                     LIT11740

      SUBROUTINE PLOT(NA,NB,NAA,NAB,NAC,NBA,NBB,NBC,INR)                      LIT11750
      IMPLICIT REAL*8 (A-H,O-Z)                                               LIT11760
      COMMON       NAME(100),A(10000),W1(80),W2(80),W3(80),W4(80)             LIT11770
     1            ,NSIZE,NUM,NX,NR,NC,NNR,NNC,NDUM,NROW(100),NCOL(100)       LIT11780
     2,NN(100),NW1(80)                                                        LIT11790
      REAL*8 NAME                                                             LIT11800
      INTEGER*2 IGRID(101)                                                    LIT11810
      INTEGER*4 ICHAR(11)/'  + ','    ','  - ','  | ','  Y ','  X ',          LIT11820
     *'  A ','  B ','  * ','  O ','  . '/                                     LIT11830
      NNN=6                                                                   LIT11840
      KKK=65                                                                  LIT11850
      IF(INR.EQ.1) NNN=8                                                      LIT11860
      IF(INR.EQ.1) KKK=81                                                     LIT11870
      KKJ=KKK-1                                                               LIT11880
      PNN=NNN                                                                 LIT11890
      XMAX=A(NA)                                                              LIT11900
      XMIN=XMAX                                                               LIT11910
      YMAX=A(NA+1)                                                            LIT11920
      YMIN=YMAX                                                               LIT11930
      IF(INR) 48,48,49                                                        LIT11940
   49 WRITE(8,99)                                                             LIT11950
   48 DO 10 K=NA,NB,2                                                         LIT11960
      IF(A(K).GT.XMAX) XMAX=A(K)                                              LIT11970
      IF(A(K).LT.XMIN) XMIN=A(K)                                              LIT11980
      IF(A(K+1).GT.YMAX) YMAX=A(K+1)                                          LIT11990
   10 IF(A(K+1).LT.YMIN) YMIN=A(K+1)                                          LIT12000
      IF(NAA.EQ.0) GO TO 60                                                   LIT12010
      DO 50 K=NAA,NBA,2                                                       LIT12020
      IF(A(K).GT.XMAX) XMAX=A(K)                                              LIT12030
      IF(A(K).LT.XMIN) XMIN=A(K)                                              LIT12040
      IF(A(K+1).GT.YMAX) YMAX=A(K+1)                                          LIT12050
   50 IF(A(K+1).LT.YMIN) YMIN=A(K+1)                                          LIT12060
```

```
      IF(NAB.EQ.0) GO TO 60                                              LIT12070
      DO 51 K=NAB,NBB,2                                                  LIT12080
      IF(A(K).GT.XMAX) XMAX=A(K)                                         LIT12090
      IF(A(K).LT.XMIN) XMIN=A(K)                                         LIT12100
      IF(A(K+1).GT.YMAX) YMAX=A(K+1)                                     LIT12110
   51 IF(A(K+1).LT.YMIN) YMIN=A(K+1)                                     LIT12120
      IF(NAC.EQ.0) GO TO 60                                              LIT12130
      DO 52 K=NAC,NBC,2                                                  LIT12140
      IF(A(K).GT.XMAX) XMAX=A(K)                                         LIT12150
      IF(A(K).LT.XMIN) XMIN=A(K)                                         LIT12160
      IF(A(K+1).GT.YMAX) YMAX=A(K+1)                                     LIT12170
   52 IF(A(K+1).LT.YMIN) YMIN=A(K+1)                                     LIT12180
   60 XRANGE=XMAX-XMIN                                                   LIT12190
      IF(XRANGE.EQ.0.0) XRANGE=1.0                                       LIT12200
      YRANGE=YMAX-YMIN                                                   LIT12210
      IF(YRANGE.EQ.0.0) YRANGE=1.0                                       LIT12220
      XT=XMAX*XMIN                                                       LIT12230
      YT=YMAX*YMIN                                                       LIT12240
      IF(YT.LT.0.0) IXAX=100.0*(-YMIN)/YRANGE+1.5                        LIT12250
      IF(XT.LT.0.0) IYAX=KKJ- KKJ*XMAX/XRANGE+1.5                        LIT12260
      IF(XMIN.GE.0.0) IYAX=1                                             LIT12270
      IF(XMAX.LE.0.0) IYAX=KKK                                           LIT12280
      IF(YMIN.GE.0.0) IXAX=1                                             LIT12290
      IF(YMAX.LE.0.0) IXAX=101                                           LIT12300
      YINCR=YRANGE/10.0                                                  LIT12310
      XINCR=PNN*(XRANGE/KKJ)                                             LIT12320
      DO  11 LINE=1,KKK                                                  LIT12330
      DO 12 J=1,101                                                      LIT12340
   12 IGRID(J)=ICHAR(2)                                                  LIT12350
      IF(LINE-IYAX) 13,14,13                                             LIT12360
   14 DO 15 K=1,101                                                      LIT12370
   15 IGRID(K)=ICHAR(3)                                                  LIT12380
      DO 25 LL=1,10                                                      LIT12390
      LY=IXAX-10*LL                                                      LIT12400
      IF(LY.LT.0.0) GO TO 26                                             LIT12410
      IGRID(LY)=ICHAR(5)                                                 LIT12420
      IF(XT.GT.0.0) IGRID(LY)=ICHAR(8)                                   LIT12430
   26 LY=IXAX+10*LL                                                      LIT12440
      IF(LY.GT.100) GO TO 25                                             LIT12450
      IGRID(LY)=ICHAR(5)                                                 LIT12460
      IF(XT.GT.0.0) IGRID(LY)=ICHAR(8)                                   LIT12470
   25 CONTINUE                                                           LIT12480
   13 IGRID(IXAX)=ICHAR(4)                                               LIT12490
      DO 27 JK=1,10                                                      LIT12500
      JX=IYAX-PNN*JK                                                     LIT12510
      IF(JX.LT.0.0) GO TO 28                                             LIT12520
      IF(JX-LINE) 28,29,28                                               LIT12530
   29 IGRID(IXAX)=ICHAR(6)                                               LIT12540
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      IF(YT.GT.0.0) IGRID(IXAX)=ICHAR(7)                                LIT12550
   28 JX=IYAX+PNN*JK                                                    LIT12560
      IF(JX.GT.KKJ) GO TO 27                                            LIT12570
      IF(JX-LINE) 27,30,27                                              LIT12580
   30 IGRID(IXAX)=ICHAR(6)                                              LIT12590
      IF(YT.GT.0.0) IGRID(IXAX)=ICHAR(7)                                LIT12600
   27 CONTINUE                                                          LIT12610
      DO 16 I=NA,NB,2                                                   LIT12620
      IPTX=KKJ-KKJ*(XMAX-A(I))/XRANGE+1.5                               LIT12630
      IF(IPTX.LT.1) IPTX=1                                              LIT12640
      IF(IPTX.GT.KKJ) IPTX=KKK                                          LIT12650
      IF(IPTX-LINE) 16,17,16                                            LIT12660
   17 IPTY=100.0*(A(I+1)-YMIN)/YRANGE+1.5                               LIT12670
      IGRID(IPTY)=ICHAR(1)                                              LIT12680
   16 CONTINUE                                                          LIT12690
      IF(NAA.EQ.0) GO TO 97                                             LIT12700
      DO 53 IA=NAA,NBA,2                                                LIT12710
      IPTX=KKJ-KKJ*(XMAX-A(IA))/XRANGE+1.5                              LIT12720
      IF(IPTX.LT.1) IPTX=1                                              LIT12730
      IF(IPTX.GT.KKJ) IPTX=KKK                                          LIT12740
      IF(IPTX-LINE) 53,67,53                                            LIT12750
   67 IPTY=100.0*(A(IA+1)-YMIN)/YRANGE+1.5                              LIT12760
      IGRID(IPTY)=ICHAR(9)                                              LIT12770
   53 CONTINUE                                                          LIT12780
      IF(NAB.EQ.0) GO TO 97                                             LIT12790
      DO 54 IB=NAB,NBB,2                                                LIT12800
      IPTX=KKJ-KKJ*(XMAX-A(IB))/XRANGE+1.5                              LIT12810
      IF(IPTX.LT.1) IPTX=1                                              LIT12820
      IF(IPTX.GT.KKJ) IPTX=KKK                                          LIT12830
      IF(IPTX-LINE) 54,66,54                                            LIT12840
   66 IPTY=100.0*(A(IB+1)-YMIN)/YRANGE+1.5                              LIT12850
      IGRID(IPTY)=ICHAR(10)                                             LIT12860
   54 CONTINUE                                                          LIT12870
      IF(NAC.EQ.0) GO TO 97                                             LIT12880
      DO 55 IC=NAC,NBC,2                                                LIT12890
      IPTX=KKJ-KKJ*(XMAX-A(IC))/XRANGE+1.5                              LIT12900
      IF(IPTX.LT.1) IPTX=1                                              LIT12910
      IF(IPTX.GT.KKJ) IPTX=KKK                                          LIT12920
      IF(IPTX-LINE) 55,68,55                                            LIT12930
   68 IPTY=100.0*(A(IC+1)-YMIN)/YRANGE+1.5                              LIT12940
      IGRID(IPTY)=ICHAR(11)                                             LIT12950
   55 CONTINUE                                                          LIT12960
   97 IF(INR) 42,42,41                                                  LIT12970
   42 WRITE(6,20) (IGRID(I),I=1,101)                                    LIT12980
      GO TO 11                                                          LIT12990
   41 WRITE(8,20) (IGRID(I),I=1,101)                                    LIT13000
   11 CONTINUE                                                          LIT13010
      IF(XT.LE.0.0) YYY=0.0                                             LIT13020
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      IF(YT.LE.0.0) XXX=0.0                                                  LIT13030
      IF(XMIN.GE.0.0) XXX=XMIN                                               LIT13040
      IF(YMAX.LE.0.0) YYY=YMAX                                               LIT13050
      IF(YMIN.GE.0.0) YYY=YMIN                                               LIT13060
      IF(XMAX.LE.0.0) XXX=XMIN+XRANGE+XINCR/PNN                              LIT13070
      IF(INR) 43,43,44                                                       LIT13080
   43 WRITE(6,22) XINCR,YINCR                                                LIT13090
      WRITE(6,23) XXX,YYY                                                    LIT13100
      GO TO 45                                                               LIT13110
   44 WRITE(8,22) XINCR,YINCR                                                LIT13120
      WRITE(8,23) XXX,YYY                                                    LIT13130
   45 RETURN                                                                 LIT13140
   20 FORMAT(15X,101A1)                                                      LIT13150
   99 FORMAT(1H1)                                                            LIT13160
   22 FORMAT(12H  X-----X = ,F6.2,10X,15H  Y---------Y = ,F6.2)              LIT13170
   23 FORMAT(11H ORGIN: X= ,F6.2,3H Y=,F6.2)                                 LIT13180
      END                                                                    LIT13190

      SUBROUTINE ITGRAL(NA,INR)                                              LIT13200
      IMPLICIT REAL*8 (A-H,O-Z)                                              LIT13210
      COMMON       XNAME(100),A(10000),W1(80),W2(80),W3(80),W4(80)           LIT13220
     1            ,NSIZE,NUM,NX,NR,NC,NNR,NNC,NDUM,NROW(100),NCOL(100)      LIT13230
     2,NN(100),NW1(80)                                                       LIT13240
      DIMENSION C(16),X(6),W(6)                                              LIT13250
      SUM=C.0D0                                                              LIT13260
      SUM2=0.0D0                                                             LIT13270
      SUM4=0.0D0                                                             LIT13280
      SUM8=0.0D0                                                             LIT13290
      SUM16=0.0D0                                                            LIT13300
      DO 9 I=1,16                                                            LIT13310
    9 C(I)=0.0D0                                                             LIT13320
      X(1)=-.93246951420315200                                               LIT13330
      X(2)=-.66120938646626450                                               LIT13340
      X(3)=-.23861918608319690                                               LIT13350
      X(4)=-X(3)                                                             LIT13360
      X(5)=-X(2)                                                             LIT13370
      X(6)=-X(1)                                                             LIT13380
      W(1)=.17132449237917030                                                LIT13390
      W(2)=.36076157304813860                                                LIT13400
      W(3)=.46791393457269100                                                LIT13410
      W(4)=W(3)                                                              LIT13420
      W(5)=W(2)                                                              LIT13430
      W(6)=W(1)                                                              LIT13440
      GO TO (1,2,3,4),INR                                                    LIT13450
    1 H=A(NA)                                                                LIT13460
      XF=A(NA+1)                                                             LIT13470
      XL=A(NA+NR-1)                                                          LIT13480
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```
      NV=NR-1                                                          LIT13490
      NNV=NR-2                                                         LIT13500
      IF(NV.LT.3) GO TO 23                                             LIT13510
      DO 20 I=3,NV,2                                                   LIT13520
   20 SUM4=SUM4+A(NA+I-1)                                              LIT13530
      IF(NNV.LT.4) GO TO 23                                            LIT13540
      DO 21 I=4,NNV,2                                                  LIT13550
   21 SUM2=SUM2+A(NA+I-1)                                              LIT13560
   23 SUM=(H/3.0)*(XF+XL+4.0*SUM4+2.0*SUM2)                            LIT13570
      WRITE(6,61) SUM                                                  LIT13580
      GO TO 99                                                         LIT13590
    2 H=A(NA)                                                          LIT13600
      HH=A(NA+1)                                                       LIT13610
      IJ=NR-2                                                          LIT13620
      ZZ=IJ                                                            LIT13630
      IK=DSQRT(ZZ)                                                     LIT13640
      NB=(IK-1)/2                                                      LIT13650
      NC=NB-1                                                          LIT13660
      ND=IK-2                                                          LIT13670
      NE=ND-1                                                          LIT13680
      NF=IK-3                                                          LIT13690
      SUM=A(NA+2)+A(NA+IK+1)+A(NA+NR-IK)+A(NA+NR-1)                    LIT13700
      DO 31 I=1,ND,2                                                   LIT13710
   31 SUM4=SUM4+A(NA+I+2)+A(NA+NR-IK+1)                                LIT13720
      IF(NF.LT.1) GO TO 30                                             LIT13730
      DO 38 I=1,NF,2                                                   LIT13740
   38 SUM2=SUM2+A(NA+I+3)+A(NA+NR-IK+2)                                LIT13750
   30 DO 32 J=1,ND,2                                                   LIT13760
      DO 32 JJ=1,ND,2                                                  LIT13770
   32 SUM16=SUM16+A(NA+J*IK+JJ+2)                                      LIT13780
      DO 33 K=1,ND,2                                                   LIT13790
      DO 33 KK=1,NE,2                                                  LIT13800
   33 SUM8=SUM8+A(NA+K*IK+KK+3)                                        LIT13810
      DO 34 L=2,NF,2                                                   LIT13820
      DO 34 LL=1,ND,2                                                  LIT13830
   34 SUM8=SUM8+A(NA+L*IK+LL+2)                                        LIT13840
      DO 35 M=2,NF,2                                                   LIT13850
      DO 35 MM=1,NE,2                                                  LIT13860
   35 SUM4=SUM4+A(NA+M*IK+MM+3)                                        LIT13870
      DO 36 MN=1,ND,2                                                  LIT13880
   36 SUM4=SUM4+A(NA+MN*IK+2)+A(NA+MN*IK+IK+1)                         LIT13890
      IF(NF.LT.2) GO TO 39                                             LIT13900
      DO 37 MNN=2,NF,2                                                 LIT13910
   37 SUM2=SUM2+A(NA+MNN*IK+2)+A(NA+MNN*IK+IK+1)                       LIT13920
   39 SUM=(SUM+2*SUM2+4*SUM4+8*SUM8+16*SUM16)*(H*HH)/9.0D0             LIT13930
      WRITE(6,62) SUM                                                  LIT13940
      GO TO 99                                                         LIT13950
    3 NB=NR-2                                                          LIT13960
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```
      XL=A(NA)                                                          LIT13970
      XU=A(NA+1)                                                        LIT13980
      DO 41 I=1,NB                                                      LIT13990
   41 C(I)=A(NA+I+1)                                                    LIT14000
      RANGE=XU-XL                                                       LIT14010
      XM=(XU+XL)/2.0D0                                                  LIT14020
      DO 42 I=1,6                                                       LIT14030
      PT=X(I)*(XU-XM)+XM                                                LIT14040
      FX=C(1)*PT**11+C(2)*PT**10+C(3)*PT**9+C(4)*PT**8+C(5)*PT**7+      LIT14050
     1C(6)*PT**6+C(7)*PT**5+C(8)*PT**4+C(9)*PT**3+C(10)*PT**2+C(11)*PT  LIT14060
     2+C(12)                                                            LIT14070
   42 SUM=FX*W(I)+SUM                                                   LIT14080
      SUM=SUM*RANGE/2.0D0                                               LIT14090
      WRITE(6,61) SUM                                                   LIT14100
      GO TO 99                                                          LIT14110
    4 NB=NR-4                                                           LIT14120
      XL=A(NA)                                                          LIT14130
      XU=A(NA+1)                                                        LIT14140
      YL=A(NA+2)                                                        LIT14150
      YU=A(NA+3)                                                        LIT14160
      XRANGE=XU-XL                                                      LIT14170
      YRANGE=YU-YL                                                      LIT14180
      XM=(XU+XL)/2.0D0                                                  LIT14190
      YM=(YU+YL)/2.0D0                                                  LIT14200
      DO 51 I=1,NB                                                      LIT14210
   51 C(I)=A(NA+I+3)                                                    LIT14220
      DO 53 I=1,6                                                       LIT14230
      DO 53 J=1,6                                                       LIT14240
      PTX=X(I)*(XU-XM)+XM                                               LIT14250
      PTY=X(J)*(YU-YM)+YM                                               LIT14260
      FX=C(1)*PTX**3*PTY**3+C(2)*PTX**3*PTY**2+C(3)*PTX**3*PTY+         LIT14270
     1C(4)*PTX**3+C(5)*PTX**2*PTY**3+C(6)*PTX**2*PTY**2+C(7)*PTX**2*PTY LIT14280
     2+C(8)*PTX**2+C(9)*PTX*PTY**3+C(10)*PTX*PTY**2+C(11)*PTX*PTY+      LIT14290
     3C(12)*PTX+C(13)*PTY**3+C(14)*PTY**2+C(15)*PTY+C(16)               LIT14300
   53 SUM=FX*W(I)*W(J)+SUM                                              LIT14310
      SUM=SUM*XRANGE*YRANGE/4.0D0                                       LIT14320
      WRITE(6,62) SUM                                                   LIT14330
   99 RETURN                                                            LIT14340
   61 FORMAT(6H AREA=,1D25.16)                                          LIT14350
   62 FORMAT(8H VOLUME=,1D25.16)                                        LIT14360
   25 FORMAT(12F6.4)                                                    LIT14370
      END                                                               LIT14380
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```
      SUBROUTINE POLFIT(XA,XB,*)                                          LIT14390
      IMPLICIT REAL *8 (A-H,O-Z)                                          LIT14400
      COMMON       XNAME(100),A(10000),W1(80),W2(80),W3(80),W4(80)        LIT14410
     1            ,NSIZE,NUM,NX,NR,NC,NNR,NNC,NDUM,NROW(100),NCOL(100)   LIT14420
     2,NN(100),NW1(80)                                                    LIT14430
      DIMENSION CM(256),COEF(16),CM1(16),PV(16),CV(16),GSP(16)            LIT14440
      NC=1                                                                LIT14450
      NR=16                                                               LIT14460
      CALL MFIND(XA,&5)                                                   LIT14470
      NA=NX                                                               LIT14480
      HX=A(NA)                                                            LIT14490
      HY=A(NA+1)                                                          LIT14500
      DO 10 I=1,16                                                        LIT14510
   10 PV(I)=A(NA+1+I)                                                     LIT14520
      L=0                                                                 LIT14530
      DO 100 I=1,4                                                        LIT14540
      Y=I-1                                                               LIT14550
      DO 100 J=1,4                                                        LIT14560
      X=J-1                                                               LIT14570
      DO 50 II=1,16                                                       LIT14580
   50 COEF(II)=0.0D0                                                      LIT14590
      CALL P(X,Y,COEF)                                                    LIT14600
      DO 70 K=1,16                                                        LIT14610
   70 CM(L*16+K)=COEF(K)                                                  LIT14620
      L=L+1                                                               LIT14630
  100 CONTINUE                                                            LIT14640
      CALL INVERT(CM,CM1,GSP,16)                                          LIT14650
      CALL MULT(16,CM,16,PV,1,CV)                                         LIT14660
      CV(1)=CV(1)/(HX**3*HY**3)                                           LIT14670
      CV(2)=CV(2)/(HX**3*HY**2)                                           LIT14680
      CV(3)=CV(3)/(HX**3*HY)                                              LIT14690
      CV(4)=CV(4)/(HX**3)                                                 LIT14700
      CV(5)=CV(5)/(HX**2*HY**3)                                           LIT14710
      CV(6)=CV(6)/(HX**2*HY**2)                                           LIT14720
      CV(7)=CV(7)/(HX**2*HY)                                              LIT14730
      CV(8)=CV(8)/(HX**2)                                                 LIT14740
      CV(9)=CV(9)/(HX*HY**3)                                              LIT14750
      CV(10)=CV(10)/(HX*HY**2)                                            LIT14760
      CV(11)=CV(11)/(HX*HY)                                               LIT14770
      CV(12)=CV(12)/(HX)                                                  LIT14780
      CV(13)=CV(13)/(HY**3)                                               LIT14790
      CV(14)=CV(14)/HY**2                                                 LIT14800
      CV(15)=CV(15)/HY                                                    LIT14810
      NR=16                                                               LIT14820
      NC=1                                                                LIT14830
      CALL MLIST(XB,&5)                                                   LIT14840
      CALL MFIND(XB,&5)                                                   LIT14850
      NA=NX                                                               LIT14860
```

```
      DO 200 I=1,16                                                    LIT14870
  200 A(NA-1+I)=CV(I)                                                  LIT14880
      RETURN                                                           LIT14890
    5 RETURN 1                                                         LIT14900
      END                                                              LIT14910

      SUBROUTINE P(X,Y,COEF)                                           LIT14920
      IMPLICIT REAL*8 (A-H,O-Z)                                        LIT14930
      DIMENSION COEF(16)                                               LIT14940
      IF(X.EQ.0.0D0.AND.Y.EQ.0.0D0) GO TO 10                           LIT14950
      GO TO 15                                                         LIT14960
   10 COEF(16)=1.0D0                                                   LIT14970
      RETURN                                                           LIT14980
   15 CONTINUE                                                         LIT14990
      IF(X.EQ.0.0D0) GO TO 20                                          LIT15000
      GO TO 25                                                         LIT15010
   20 COEF(13)=Y**3                                                    LIT15020
      COEF(14)=Y**2                                                    LIT15030
      COEF(15)=Y                                                       LIT15040
      COEF(16)=1.0D0                                                   LIT15050
      RETURN                                                           LIT15060
   25 CONTINUE                                                         LIT15070
      IF(Y.EQ.0.0D0) GO TO 30                                          LIT15080
      GO TO 35                                                         LIT15090
   30 COEF(4)=X**3                                                     LIT15100
      COEF(8)=X**2                                                     LIT15110
      COEF(12)=X                                                       LIT15120
      COEF(16)=1.0D0                                                   LIT15130
      RETURN                                                           LIT15140
   35 CONTINUE                                                         LIT15150
      COEF(1)=(X**3)*(Y**3)                                            LIT15160
      DO 100 I=2,5                                                     LIT15170
      IM=I-1                                                           LIT15180
      IF(I.GT.4) GO TO 50                                              LIT15190
      COEF(I)=COEF(IM)/Y                                               LIT15200
   50 CONTINUE                                                         LIT15210
      DO 100 J=2,4                                                     LIT15220
      JJ=(J-1)*4+IM                                                    LIT15230
      JM=JJ-4                                                          LIT15240
      COEF(JJ)=COEF(JM)/X                                              LIT15250
  100 CONTINUE                                                         LIT15260
      RETURN                                                           LIT15270
      END                                                              LIT15280
```

```
      SUBROUTINE CONTUR(XA,XB,NAR,NAC,NOC,*)                                LIT15290
      IMPLICIT REAL*8 (A-H,O-Z)                                             LIT15300
      COMMON       XNAME(100),A(10000),W1(80),W2(80),W3(80),W4(80)          LIT15310
     1            ,NSIZE,NUM,NX,NR,NC,NNR,NNC,NDUM,NROW(100),NCOL(100)     LIT15320
     2,NN(100),NW1(80)                                                      LIT15330
      DIMENSION  ISYMB(42),BV(21),C(16),IGRID(101),U(16)                    LIT15340
      INTEGER*2 GRAPH(16),GRAPH1(16),GRAPH2(16),GRAPH3(16),GRAPH4(16)       LIT15350
      DATA ISYMB/1H ,1HO,1H ,1HA,1H ,1HB,1H ,1HC,1H ,1HD,1H ,1HE            LIT15360
     1,1H ,1HF,1H ,1HG,1H ,1HH,1H ,1HI,1H ,1HJ,1H ,1HQ,1H ,1HR,1H ,1HS,    LIT15370
     21H ,1HT,1H ,1HU,1H ,1HV,1H ,1HW,1H ,1HX,1H ,1HY,1H ,1HZ/              LIT15380
      DATA IBLK/1H /                                                        LIT15390
      DATA GRAPH /'U1-------U2--------U3--------U4 '/                        LIT15400
      DATA GRAPH1/'U5-------U6--------U7--------U8 '/                        LIT15410
      DATA GRAPH2/'U9-------U10-------U11-------U12'/                        LIT15420
      DATA GRAPH3/'U13------U14-------U15-------U16'/                        LIT15430
      DATA GRAPH4/'|         |         |         | '/                        LIT15440
      GO TO (474,475),NAR                                                   LIT15450
  474 CALL POLFIT(XA,XB,P5)                                                 LIT15460
      CALL MFIND(XA,&5)                                                     LIT15470
      NA=NX                                                                 LIT15480
      HX=A(NA)                                                              LIT15490
      HY=A(NA+1)                                                            LIT15500
      XL=0.0D0                                                              LIT15510
      YL=0.0D0                                                              LIT15520
      XRANGE=3.0D0*HX                                                       LIT15530
      YRANGE=3.0D0*HY                                                       LIT15540
      CALL MFIND(XB,&5)                                                     LIT15550
      NB=NX                                                                 LIT15560
      DO 476 I=1,16                                                         LIT15570
      U(I) =A(NA+1+I)                                                       LIT15580
  476 C(I)=A(NB+I-1)                                                        LIT15590
      GO TO 480                                                             LIT15600
  475 CALL MFIND(XA,&5)                                                     LIT15610
      NA=NX                                                                 LIT15620
      XL=A(NA)                                                              LIT15630
      XU=A(NA+1)                                                            LIT15640
      YL=A(NA+2)                                                            LIT15650
      YU=A(NA+3)                                                            LIT15660
      XRANGE=XU-XL                                                          LIT15670
      YRANGE=YU-YL                                                          LIT15680
      DO 477 I=1,16                                                         LIT15690
  477 C(I)=A(NA+I+3)                                                        LIT15700
  480 IJK=65                                                                LIT15710
      IF(NAC.GT.1) IJK=80                                                   LIT15720
      PJK=IJK-1.0                                                           LIT15730
      GO TO (20,21),NAC                                                     LIT15740
   20 GO TO (1,2),NAR                                                       LIT15750
    1 WRITE(6,101)                                                          LIT15760
```

```
      WRITE(6,300) GRAPH                                                LIT15770
      DO 6 I=1,6                                                        LIT15780
    6 WRITE(6,300) GRAPH4                                               LIT15790
      WRITE(6,300) GRAPH1                                               LIT15800
      DO 7 I=1,6                                                        LIT15810
    7 WRITE(6,300) GRAPH4                                               LIT15820
      WRITE(6,300) GRAPH2                                               LIT15830
      DO 8 I=1,6                                                        LIT15840
    8 WRITE(6,300) GRAPH4                                               LIT15850
      WRITE(6,300) GRAPH3                                               LIT15860
      WRITE(6,101)                                                      LIT15870
      WRITE(6,301) U(1),U(2),U(3),U(4),U(5),U(6),U(7),U(8)              LIT15880
      WRITE(6,302) U(9),U(10),U(11),U(12),U(13),U(14),U(15),U(16)       LIT15890
      JMB=4-NOC                                                         LIT15900
      DO 60 L=1,JMB                                                     LIT15910
   60 WRITE(6,100)                                                      LIT15920
      GO TO 4                                                           LIT15930
    2 WRITE(6,103)                                                      LIT15940
      WRITE(6,303) C(1),C(2),C(3),C(4),C(5),C(6),C(7),C(8)              LIT15950
      WRITE(6,304) C(9),C(10),C(11),C(12),C(13),C(14),C(15),C(16)       LIT15960
      JMB=20-NOC                                                        LIT15970
      DO 61 L=1,JMB                                                     LIT15980
   61 WRITE(6,100)                                                      LIT15990
      GO TO 4                                                           LIT16000
   21 GO TO (22,23),NAR                                                 LIT16010
   22 WRITE(8,101)                                                      LIT16020
      WRITE(8,300) GRAPH                                                LIT16030
      DO 24 I=1,8                                                       LIT16040
   24 WRITE(8,300) GRAPH4                                               LIT16050
      WRITE(8,300) GRAPH1                                               LIT16060
      DO 25 I=1,8                                                       LIT16070
   25 WRITE(8,300) GRAPH4                                               LIT16080
      WRITE(8,300) GRAPH2                                               LIT16090
      DO 26 I=1,8                                                       LIT16100
   26 WRITE(8,300) GRAPH4                                               LIT16110
      WRITE(8,300) GRAPH3                                               LIT16120
      WRITE(8,101)                                                      LIT16130
      WRITE(8,301) U(1),U(2),U(3),U(4),U(5),U(6),U(7),U(8)              LIT16140
      WRITE(8,302) U(9),U(10),U(11),U(12),U(13),U(14),U(15),U(16)       LIT16150
      JMB=6-NOC                                                         LIT16160
      DO 62 L=1,NCC                                                     LIT16170
   62 WRITE(8,100)                                                      LIT16180
      GO TO 4                                                           LIT16190
   23 WRITE(8,105)                                                      LIT16200
      WRITE(8,303) C(1),C(2),C(3),C(4),C(5),C(6),C(7),C(8)              LIT16210
      WRITE(8,304) C(9),C(10),C(11),C(12),C(13),C(14),C(15),C(16)       LIT16220
      JMB=9-NOC                                                         LIT16230
      DO 63 L=1,JMB                                                     LIT16240
```

```
63 WRITE(8,100)                                                                 LIT16250
 4 PMAX=-1.0D70                                                                 LIT16260
   PMIN= 1.0D70                                                                 LIT16270
   DO 10 I=1,IJK                                                                LIT16280
   DO 10 J=1,101                                                                LIT16290
   X1=J-1                                                                       LIT16300
   Y1=I-1                                                                       LIT16310
   X=XL+(XRANGE*X1)/100.0D0                                                     LIT16320
   Y=YL+(YRANGE*Y1)/PJK                                                         LIT16330
   PP=C(1)*X**3*Y**3+C(2)*X**3*Y**2+C(3)*X**3*Y+C(4)*X**3 +                     LIT16340
  1C(5)*X**2*Y**3+C(6)*X**2*Y**2+C(7)*X**2*Y+C(8)*X**2+C(9)*X*Y**3+             LIT16350
  2C(10)*X*Y**2+C(11)*X*Y+C(12)*X+C(13)*Y**3+C(14)*Y**2+C(15)*Y+C(16)           LIT16360
   IF(PP.GT.PMAX) PMAX=PP                                                       LIT16370
10 IF(PP.LT.PMIN) PMIN=PP                                                       LIT16380
   RANGE=PMAX-PMIN                                                              LIT16390
   IF(DABS(RANGE).GT.1.0D-10) GO TO 11                                          LIT16400
   WRITE(6,1000)                                                                LIT16410
   WRITE(6,1400) RANGE,PMAX,MIN                                                 LIT16420
   GO TO 1500                                                                   LIT16430
11 SCF=40./RANGE                                                                LIT16440
   DO 12 I=1,21                                                                 LIT16450
   RR=I-1                                                                       LIT16460
12 BV(I)=2*RR/SCF+PMIN                                                          LIT16470
   GO TO (30,31),NAC                                                            LIT16480
30 WRITE(6,1300) BV(1),BV(1),BV(21)                                             LIT16490
   WRITE(6,1100) BV(2),BV(3),BV(4),BV(5),BV(6)                                  LIT16500
   WRITE(6,1200) BV(7),BV(8),BV(9),BV(10),BV(11)                                LIT16510
   WRITE(6,1210) BV(12),BV(13),BV(14),BV(15),BV(16)                             LIT16520
   WRITE(6,1220) BV(17),BV(18),BV(19),BV(20),BV(21)                             LIT16530
   WRITE(6,102)                                                                 LIT16540
   GO TO 40                                                                     LIT16550
31 WRITE(8,1300) BV(1),BV(1),BV(21)                                             LIT16560
   WRITE(8,1100) BV(2),BV(3),BV(4),BV(5),BV(6)                                  LIT16570
   WRITE(8,1200) BV(7),BV(8),BV(9),BV(10),BV(11)                                LIT16580
   WRITE(8,1210) BV(12),BV(13),BV(14),BV(15),BV(16)                             LIT16590
   WRITE(8,1220) BV(17),BV(18),BV(19),BV(20),BV(21)                             LIT16600
   WRITE(8,104)                                                                 LIT16610
40 CONTINUE                                                                     LIT16620
   DO 13 I=1,IJK                                                                LIT16630
   DO 14 K=1,101                                                                LIT16640
14 IGRID(K)=IBLK                                                                LIT16650
   DO 15 J=1,101                                                                LIT16660
   X1=J-1                                                                       LIT16670
   Y1=I-1                                                                       LIT16680
   X=XL+(XRANGE*X1)/100.0D0                                                     LIT16690
   Y=YL+(YRANGE*Y1)/PJK                                                         LIT16700
   PP=C(1)*X**3*Y**3+C(2)*X**3*Y**2+C(3)*X**3*Y+C(4)*X**3 +                     LIT16710
  1C(5)*X**2*Y**3+C(6)*X**2*Y**2+C(7)*X**2*Y+C(8)*X**2+C(9)*X*Y**3+             LIT16720
```

```
     2C(10)*X*Y**2+C(11)*X*Y+C(12)*X+C(13)*Y**3+C(14)*Y**2+C(15)*Y+C(16)LIT16730
      KK=((PP-PMIN)*SCF+2.50001)                                        LIT16740
   15 IGRID(J)=ISYMB(KK)                                                LIT16750
      GO TO (50,51),NAC                                                 LIT16760
   50 WRITE(6,99) (IGRID(II),II=1,101)                                  LIT16770
      GO TO 13                                                          LIT16780
   51 WRITE(8,99) (IGRID(II),II=1,101)                                  LIT16790
   13 CONTINUE                                                          LIT16800
      IF(NAC.EQ.1) WRITE(6,102)                                         LIT16810
      IF(NAC.EQ.2) WRITE(8,104)                                         LIT16820
   99 FORMAT(15X,101A1)                                                 LIT16830
  100 FORMAT(/)                                                         LIT16840
  101 FORMAT(////)                                                      LIT16850
  102 FORMAT(///////)                                                   LIT16860
  103 FORMAT(////)                                                      LIT16870
  104 FORMAT(1H1)                                                       LIT16880
  105 FORMAT(////////////)                                              LIT16890
  300 FORMAT(25X,16A2)                                                  LIT16900
  301 FORMAT(15X,5H U1 =,F12.6,5H U2 =,F12.6,5H U3 =,F12.6,5H U4 =,     LIT16910
     1F12.6,//,15X,5H U5 =,F12.6,5H U6 =,F12.6,5H U7 =,F12.6,5H U8 =,   LIT16920
     2F12.6,/)                                                          LIT16930
  302 FORMAT(15X,5H U9 =,F12.6,5H U10=,F12.6,5H U11=,F12.6,5H U12=,     LIT16940
     1F12.6,//,15X,5H U13=,F12.6,5H U14=,F12.6,5H U15=,F12.6,5H U16=,   LIT16950
     2F12.6,////)                                                       LIT16960
  303 FORMAT(15X,F12.6,5H X3Y3,F12.6,5H X3Y2,F12.6,5H X3Y ,F12.6,       LIT16970
     15H X3  ,//,15X,F12.6,5H X2Y3,F12.6,5H X2Y2,F12.6,5H X2Y ,F12.6,   LIT16980
     25H X2  ,/)                                                        LIT16990
  304 FORMAT(15X,F12.6,5H XY3 ,F12.6,5H XY2 ,F12.6,5H XY  ,F12.6,       LIT17000
     15H X   ,//,15X,F12.6,5H Y3  ,F12.6,5H Y2  ,F12.6,5H Y   ,F12.6)  LIT17010
 1400 FORMAT(//,5X,13H THE RANGE IS,E15.6,/,5X,13H   MAXIMUM IS,E15.6,/,LIT17020
     15X,13H   MINIMUM IS,E15.6)                                        LIT17030
 1000 FORMAT(1H1)                                                       LIT17040
 1050 FORMAT(//)                                                        LIT17050
 1100 FORMAT(5X,3H A=,F12.4,3X,3H B=,F12.4,3X,3H C=,F12.4,3X,3H D=,F12.4LIT17060
     1,3X,3H E=,F12.4,/)                                                LIT17070
 1200 FORMAT(5X,3H F=,F12.4,3X,3H G=,F12.4,3X,3H H=,F12.4,3X,3H I=,F12.4LIT17080
     1,3X,3H J=,F12.4,/)                                                LIT17090
 1210 FORMAT(5X,3H Q=,F12.4,3X,3H R=,F12.4,3X,3H S=,F12.4,3X,3H T=,F12.4LIT17100
     1,3X,3H U=,F12.4,/)                                                LIT17110
 1220 FORMAT(5X,3H V=,F12.4,3X,3H W=,F12.4,3X,3H X=,F12.4,3X,3H Y=,F12.4LIT17120
     1,3X,3H Z=,F12.4,/)                                                LIT17130
 1300 FORMAT(5X,3H O=,F15.10,5X,7H RANGE(,E15.6,5X,E15.6,2H ),/)        LIT17140
 1500 RETURN                                                            LIT17150
    5 RETURN 1                                                          LIT17160
      END                                                               LIT17170
```

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13. ABSTRACT

The Matrix Interpretive System devised by Wilson and modified by Cantin has been transformed into an interactive program operable under a time sharing system. Several new commands have been added to extend the usefulness of the code and give it the capability to offline read, write and punch data, to plot graphs and contour maps and to integrate simple polynomial expressions.

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